

AD-734440

THE PROCUREMENT PROCESS AND  
PROGRAM COST OUTCOMES: A SYSTEMS APPROACH

A Thesis  
Submitted to the Faculty  
of  
Purdue University  
by  
Richard Stephen Sapp  
In Partial Fulfillment of the  
Requirements for the Degree  
of  
Doctor of Philosophy  
June 1971

EXPERIMENT A  
Not for public release  
Distribution Unlimited

REPRODUCED FROM  
BEST AVAILABLE COPY

44 DDC  
RECEIVED  
DEC 14 1971  
C

Security Classification

## DOCUMENT CONTROL DATA - R &amp; D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Air Force Institute of Technology (AFIT-CID)  
Wright-Patterson AFB, Ohio 45433

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

The Procurement Process and Program Cost Outcomes: A Systems Approach

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final, Ph.D. Thesis, Purdue University, Industrial Engineering Dept

5. AUTHOR(S) (First name, middle initial, last name)

Richard S. Sapp  
Major, USAF

6. REPORT DATE

June, 1971

7a. TOTAL NO. OF PAGES

226

7b. NO. OF REFS

57

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

ar  
be  
ncAPPROVED FOR PUBLIC RELEASE:  
DISTRIBUTION UNLIMITED

11. SUPPLEMENTARY NOTES

AFIT-CID

Wright-Patterson AFB, Ohio

13. ABSTRACT

A systems approach is used to view the process by which the Department of Defense acquires and modifies its major weapon systems. Attention is focused on the program cost outcomes of this procurement process. The research seeks out the causes of why the final cost of a defense program or contract differs from earlier estimates.

The evolution of the term cost overrun into cost growth is traced. Systems diagramming is used to develop a model of the procurement process. The model demonstrates the multiplicity of relationships affecting defense programs. It also serves as a vehicle to relate the myriad of proffered reasons to explain cost variances. Recent efforts to explain or predict cost outcomes are classified into four approaches.

Cost growth is not endemic to weapon system acquisitions. The phenomena has occurred in Class IV and V modification programs of the Air Force Logistics Command. Case histories of two active

FORM  
1 NOV 65

1473

Security Classification

**LINK A**

**LINK B**

LINK C

**ROLE**

WT

NAME	ROLE
Mr. J. Edgar Hoover	Director
Mr. Clegg	Chief Clerk
Mr. Glavin	Assistant Director
Mr. Ladd	Assistant Director
Mr. Nichols	Assistant Director
Mr. Rosen	Assistant Director
Mr. Tracy	Assistant Director
Mr. Egan	Assistant Director
Mr. Gurnea	Assistant Director
Mr. Harbo	Assistant Director
Mr. Hendon	Assistant Director
Mr. Pennington	Assistant Director
Mr. Quinn	Assistant Director
Mr. Nease	Assistant Director
Mr. Tamm	Assistant Director
Mr. Winterrowd	Assistant Director
Mr. Mohr	Assistant Director
Mr. Casper	Assistant Director
Mr. Callahan	Assistant Director
Mr. Connelley	Assistant Director
Mr. Felt	Assistant Director
Mr. Gale	Assistant Director
Mr. Rosen	Assistant Director
Mr. Sullivan	Assistant Director
Mr. Tavel	Assistant Director
Mr. Trotter	Assistant Director
Mr. Tele. Room	Telephone Room
Miss Gandy	Miss Gandy

WT

NAME	ROLE
Mr. J. Edgar Hoover	Director
Mr. Clegg	Chief of Bureau
Mr. Glavin	Chief of Bureau
Mr. Ladd	Chief of Bureau
Mr. Nichols	Chief of Bureau
Mr. Rosen	Chief of Bureau
Mr. Tracy	Chief of Bureau
Mr. Carson	Chief of Bureau
Mr. Egan	Chief of Bureau
Mr. Gurnea	Chief of Bureau
Mr. Hendon	Chief of Bureau
Mr. Pennington	Chief of Bureau
Mr. Quinn	Chief of Bureau
Mr. Nease	Chief of Bureau
Mr. Gandy	Chief of Bureau

WT

## Contracts

## Cost Growth

## Cost Overruns

**Government Procurement**

**ARMED AND DANGEROUS**

## DISCLAIMER

The views expressed herein are those of the author and do not necessarily reflect the views of the Air University, United States Air Force, or Department of Defense.



iii

To Arcene

## ACKNOWLEDGMENTS

I would like to express my appreciation and thanks to those who contributed to this dissertation and my education.

To the United States Air Force and the American taxpayers: For their financial support of my graduate studies. Both will benefit in the short and long term from an officer corps trained in the questioning, scientific manner and more attuned to the university and civilian communities.

To my Graduate Advisory Committee: For their guidance and counsel: To Professors Harold T. Amrine and James W. Barany of the Industrial Engineering Department. To Professor Virgil L. Anderson, Department of Statistics, for an increased understanding of statistics and its role in the hierarchy of research. To Ruddell Reed, Jr., my major Professor, for encouragement to investigate a real-world problem and his realistic, but demanding approach, to perform the same.

To Air Force Logistics Command personnel: For their willing contributions of time, knowledge, and experiences. Especially Solomon Arnovitz for his

sponsorship and assistance, Major General A. J. Dreiseszun  
 for permission, and Mr. Carl Wilhelm for help and construc-  
 tive suggestions.

To my family: For their understanding and patience.

## TABLE OF CONTENTS

	Page
LIST OF TABLES . . . . .	viii
LIST OF FIGURES. . . . .	x
LIST OF ABBREVIATIONS AND ACRONYMS . . . . .	xi
ABSTRACT . . . . .	xv
CHAPTER	
I. INTRODUCTION . . . . .	1
Objective of the Research. . . . .	1
Scope of the Investigation . . . . .	1
Organization of the Thesis . . . . .	2
II. BACKGROUND . . . . .	4
The Procurement Process. . . . .	5
Significance of the Problem. . . . .	10
The Need for Research. . . . .	11
On the Cost Growth Phenomena . . . . .	14
Evolution and Definition. . . . .	14
Causes or Categories. . . . .	21
Studies and Data. . . . .	22
III. PROCESS ANALYSIS . . . . .	25
Literature and Data Search . . . . .	25
Case Histories . . . . .	31
Program Selection . . . . .	34
Data Collection . . . . .	36
Program Synopses. . . . .	37
The Modification - Acquisition Hypothesis . . . . .	40
IV. PROCESS SYNTHESIS. . . . .	43
A Model of the Procurement Process . . . . .	43
Systems in General. . . . .	44
The Aerospace Contractor as a System. . . . .	46
A Four System Model . . . . .	47

CHAPTER	Page
Further Expansion of the Model . . .	53
In Review. . . . .	54
Mathematical Models . . . . .	56
The Cost-Accounting Approach . . . . .	62
The Cost-Category Approach . . . . .	63
Adjustments. . . . .	67
The Predictive-Functional Approach . . . . .	68
Example: Cost-Schedule-	
Performance. . . . .	70
Literature Examples. . . . .	71
Model Factors. . . . .	74
V. PROCESS EVALUATION. . . . .	79
Data Collection . . . . .	80
Program History. . . . .	80
Tracks and Trade-Offs. . . . .	81
Cost Summary . . . . .	83
Supplemental Data. . . . .	87
Data Analysis . . . . .	89
Evaluation of Case History Programs . . . . .	91
The C-130 Program. . . . .	96
The B-52 Program . . . . .	99
VI. CLOSURE . . . . .	103
Summary . . . . .	103
Conclusions . . . . .	106
Recommendations . . . . .	110
BIBLIOGRAPHY. . . . .	114
APPENDICES	
Appendix A: Glossary of Terms. . . . .	119
Appendix B: C-130 Center Wing Program. . . . .	125
Appendix C: B-52 Stability Augmentation	
System Program . . . . .	168
Appendix D: An Excursus on Researching	
Defense Procurement. . . . .	212
VITA. . . . .	225

## LIST OF TABLES

Table	Page
1. AFLC Modification Budget Program Accounts . . .	35
2. Procurement Model Flows . . . . .	51
3. Cost Outcome - Factors and Levels . . . . .	75
4. Modification Program Cost (MPC) . . . . .	84
5. Program Cost-Change-Cause Table . . . . .	90
6. USAF C-130 Center Wing Program. . . . .	97
7. B-52 Stability Augmentation System Program. . .	100

Appendix  
Table

1B. Cost/Fee Breakout for Contract F09603-68-C-1335. . . . .	135
2B. Cost/Fee Breakout for Contract F09603-71-0700. . . . .	136
3B. Estimated Costs/Schedule, WRAMA Briefing. . . .	140
4B. Estimated Costs/Schedule, Advance Procurement Plan. . . . .	143
5B. Cost Track - Approved . . . . .	155
6B. Cost Tracks - Contract F09603-68-C-2530 . . . .	156
7B. Cost Track - AFLC Form 48 and Budget Programs. . . . .	158
8B. Total USAF Cost for C-130 Center Wing Program . . . . .	159
9B. C-130 Center Wing Aircraft Modification Schedule. . . . .	160

Appendix Table	Page
1C. Initial Modification Program Directive Cost Breakout . . . . .	177
2C. ECP 1195 Kit Deliveries . . . . .	185
3C. Group B Components - Accessories. . . . .	194
4C. AFLC Form 48 Cost Breakout. . . . .	198
5C. Current Modification Program Directive Cost Breakout . . . . .	198
6C. Modification Number 10007 Cost Breakout . . . .	199
7C. B-52 Stability Augmentation System Installation Schedule - Actual. . . . .	201

## LIST OF FIGURES

Figure	Page
1. The Procurement Process: Phases and Segments . . . . .	32
2. Generalized System Diagram . . . . .	45
3. Four System Procurement Model. . . . .	48
4. Generalized System Representation. . . . .	50
5. Performance Contour Map. . . . .	70
6. Stacked Time Graph: C-130 Program . . . . .	92
7. Stacked Time Graph: B-52 Program. . . . .	94
Appendix	
Figure	
B1. C-130 Center Wing Program Summary. . . . .	126
B2. Aircraft Flowtime. . . . .	161
C1. B-52 Stability Augmentation System Program Summary. . . . .	170



## LIST OF ABBREVIATIONS AND ACRONYMS

AF	-	Air Force
AFB	-	Air Force Base
AFLC	-	Air Force Logistics Command
AFR	-	Air Force Regulation
AFSC	-	Air Force Systems Command
AGE	-	Aerospace Ground Equipment
AMA	-	Air Materiel Area
APP	-	Advanced Procurement Plan
ASD	-	Aeronautical Systems Division
ASPR	-	Armed Services Procurement Regulation
BP	-	Budget Program
CCB	-	Configuration Control Board
CCP	-	Contractor Change Proposal
CFE	-	Contractor Furnished Equipment
CG	-	Cost Growth
CO	-	Cost Overrun
CP	-	Contract Price
CPFF	-	Cost Plus Fixed Fee
CPIF	-	Cost Plus Incentive Fee
C/SCSC	-	Cost/Schedule Control System Criteria
CY	-	Calendar Year
DCS	-	Deputy Chief of Staff

DOD - Department of Defense  
DODI - Department of Defense Instruction  
ECP - Engineering Change Proposal  
EMI - Electromagnetic Interference  
ETP - Engineering Test Proposal  
FFP - Firm Fixed Price  
FLMP - Fatigue Life Monitoring Program  
FM - Form  
FOUO - For Official Use Only  
FPI - Fixed Price Incentive  
FPIF - Fixed Price Incentive Fee  
FPIS - Fixed Price Incentive, Successive Targets  
FY - Fiscal Year  
GAO - General Accounting Office  
GFAE - Government Furnished Aeronautical Equipment  
GFE - Government Furnished Equipment  
GFM - Government Furnished Material  
HQ - Headquarters  
I&L - Installations and Logistics  
IM - Inventory Manager  
IRAN - Inspect and Repair as Necessary  
LCC - Life Cycle Costing  
MAC - Military Airlift Command  
MIPR - Military Interdepartmental Purchase Request  
MM - Materiel Management  
NPC - Modification Program Cost

MPD - Modification Program Directive  
MTBF - Mean Time Between Failure  
MTU - Mobile Training Unit  
MUCO - Materiel Utilization Control Office  
O&M - Operation and Maintenance  
OASD - Office of Assistant Secretary of Defense  
OCAMA - Oklahoma City Air Materiel Area  
OOAMA - Ogden Air Materiel Area  
OSD - Office of Secretary of Defense  
PACAF - Pacific Air Force  
PM - Procurement Method  
PP - Procurement and Production  
PR - Purchase Request  
R&D - Research and Development  
S&L - Systems and Logistics  
SAAMA - San Antonio Air Materiel Area  
SAC - Strategic Air Command  
SAR - Selected Acquisition Report  
SAS - Stability Augmentation System  
SEA - Southeast Asia  
SMAMA - Sacramento Air Materiel Area  
SPO - System Program Office  
SSM - System Support Manager  
TAC - Tactical Air Command  
TC - Type of Contract  
USAF - United States Air Force

(

USCG - United States Coast Guard

USN - United States Navy

WRAMA - Warner-Robins Air Materiel Area

(

(

## ABSTRACT

Sapp, Richard Stephen. Ph.D., Purdue University, June 1971. The Procurement Process and Program Cost Outcomes: A Systems Approach. Major Professor: Ruddell Reed, Jr.

A systems approach is used to view the process by which the Department of Defense acquires and modifies its major weapon systems. Attention is focused on the program cost outcomes of this procurement process. The research seeks out the causes of why the final cost of a defense program or contract differs from earlier estimates.

The evolution of the term cost overrun into cost growth is traced. Systems diagramming is used to develop a model of the procurement process. The model demonstrates the multiplicity of relationships affecting defense programs. It also serves as a vehicle to relate the myriad of proffered reasons to explain cost variances. Recent efforts to explain or predict cost outcomes are classified into four approaches.

Cost growth is not endemic to weapon system acquisitions. The phenomena has occurred in Class IV and V modification programs of the Air Force Logistics Command. Case histories of two active Class IV, aircraft

modification programs were compiled: C-130 Center Wing Replacement and B-52 Stability Augmentation System Installation. The research indicates that large modification programs are microcosms of systems acquisitions and incur cost growth for similar reasons. The research also indicates the total modification program cost is not fully recognized. A methodology for further investigation is proposed.

## CHAPTER I

### INTRODUCTION

#### Objective of the Research

The objective of this research is to provide a better understanding of the nature of the United States Department of Defense procurement process for the acquisition and modification of weapon systems. More specifically, the research is directed at determining the causes of program cost outcomes, thereby enabling recommendations to be developed in an effort to reduce or minimize unwarranted program cost growths. The objective of this research is to be attained in part by using the systems approach.

#### Scope of the Investigation

The research effort is concentrated on the Air Force Logistics Command modification program for aircraft. However, since all the Military Services of the Department of Defense operate under the same procurement policy, and since many United States Air Force procurement procedures are applicable intracommand, the research may extend beyond these bounds. Generalizations can be made

and conclusions drawn which indicate implications beyond the aircraft modification program of the Air Force Logistics Command.

### Organization of the Thesis

This thesis is organized according to the three phases of the methodology of engineering design: analysis, synthesis, and evaluation. In the chapters titled Background and Process Analysis, the problem is formulated and necessary background information provided. The method used to analyze Air Force Logistics Command modification programs is also described. In the chapter titled Process Synthesis, graphical and mathematical models are constructed and examined to gain insight into the nature of the procurement process and resultant cost outcomes. The evaluation phase of this thesis encompasses the last two chapters, Process Evaluation and Closure. In Process Evaluation a classification scheme of causal factors and a format for use in future investigation is proposed. Closure summarizes the results gleaned through this research.

The Appendices were designed with the reader in mind. A Glossary of Terms is included, then two case histories of aircraft modification programs are presented. The detailed histories, which were painstakingly gathered and pieced together, are placed in the



Appendices. Their placement should facilitate reading of the main body of the thesis, yet aid in understanding modification program details. Appendix D relates some 'lessons learned' and offers guidelines for those contemplating doing research in defense procurement.

## CHAPTER II

### BACKGROUND

In this chapter background material will be presented. The specific problem being addressed and its significance are discussed. The general framework of the Department of Defense (DOD) procurement process is described, and the part played in this process by the Air Force Logistics Command (AFLC) presented. Sections on the need for this research and the cost growth phenomena conclude the chapter.

As stated in the Introduction, the problem this research addresses is the determination of the causes of defense program cost outcomes. To solve this problem requires some understanding of the procurement process; its structure, relationships and operation. If the process is understood, meaningful and effective recommendations should be forthcoming. These recommendations may aid to eliminate or reduce unfavorable program cost outcomes, commonly, and often erroneously, referred to as cost overruns. The desired aim of this research is to provide persons in Government and Industry, as well as the general public, greater insight into the

defense procurement process, so that intelligent and meaningful policies and procedures can be promulgated.

The terms 'procurement' and 'procurement process' will be used frequently. They will refer to the process by which the Government, and in particular the Department of Defense, obtains supplies and services from commercial or industrial sources. The Armed Services Procurement Regulation (ASPR) (1) defines procurement as:

The purchasing, renting, leasing, or otherwise obtaining supplies or services. It also includes all functions that pertain to the obtaining of supplies and services, including description but not determination of requirements, selection and solicitation of sources, preparation and award of contract, and all phases of contract administration.

This and other significant terms used in this dissertation are listed in the Glossary of Terms, Appendix A.

### The Procurement Process

Agencies of the Government, such as the Military Departments, have only that authority to act which Congress or the President chooses to delegate. The authority delegated to the Armed Services has been codified by Congress into Title 10 of the United States Code. Chapter 137 of Title 10 contains the procurement authority for the Armed Services. Executive Orders, Decisions of the Comptroller General, and rulings by the Armed

Services Board of Contract Appeals and Federal Courts also bear on DOD procurement activities and shape its course.

The detailed written guidance and instructions for military procurement are to be found in a number of publications. The Armed Services Procurement Regulation (ASPR) is issued by the Assistant Secretary of Defense (Installations and Logistics) and contains Defense Department policies and procedures to be complied with by all the Military Departments. Defense Procurement Circulars disseminate special detailed procurement information and serve as a bridge between revisions of ASPR. The Air Force implements the ASPR and establishes uniform procedures and instructions through the USAF ASPR Supplements. In addition, manuals, regulations, pamphlets, letters and operating instructions are published by Air Force and its major commands and subcommands to provide further supplemental guidance and instruction. These publications prescribe procurement methods and procedures for supplies and services.

The procurement decisions of what and how many to buy, maintain and modify, spread downward from the highest levels of the Executive and Legislative Branches of the Government to Military Departments, commands and subcommands, based on domestic and foreign policy decisions, national objectives and security considerations.

These policy decisions are subject to annual review and revision by virtue of the authorization and appropriation process for the Department of Defense (DOD) budget. The differences in opinion on policy and security are brought into sharp focus by the allocations of money to support the proposed military force structures; structures which must effectively and efficiently serve as an instrument of national policy. The allocated monies will decide how many of a particular system may be bought, maintained, modified and/or operated.

The Department of the Air Force is one of three military departments of the Department of Defense and is comprised of a number of major commands, separate operating agencies and staff organizations. The procurement process for the acquisition and support of Air Force systems is the responsibility of two major Air Force commands: the Air Force Systems Command (AFSC), with headquarters at Andrews AFB, Maryland; and the Air Force Logistics Command (AFLC), with headquarters at Wright-Patterson AFB, Ohio. The chain of command for these organizations to DOD is through Headquarters, United States Air Force (HQ USAF) located at the Pentagon, Washington, D.C. Basically, AFSC is responsible for the research, development and acquisition of Air Force systems and equipment; AFLC is charged with the responsibility of supporting, maintaining and modifying these

systems and equipment during their operational phase in the Air Force inventory.

The mission of AFLC is accomplished through an organization consisting of five Air Materiel Areas (AMA), two Procurement Regions and other operating agencies. The logistics support management responsibilities for Air Force resources are assigned among the five AMAs which are located at San Antonio, Texas; Sacramento, California; Oklahoma City, Oklahoma; Warner-Robins, Georgia; and Ogden, Utah. Resource assignment is made on a system or equipment basis. As an example, for aircraft systems, the C-5 is assigned to San Antonio (SAAMA), the F-105 to Sacramento (SMAMA), the B-52 to Oklahoma City (OCAMA), the C-141 to Warner-Robins (WRAMA) and the F-4 to Ogden (OOAMA). Common equipment items, such as instruments, engines and landing gear components are distributed in a similar fashion.

A more complete description of defense procurement and Air Force procurement may be found in Congressional hearings to establish a Commission on Government Procurement. (2)(3)

Distinction is made in AFLC between modernization and maintenance programs for systems and equipment. The systems and equipment are divided among three basic categories: aircraft, missiles and others. In both cases the separation is directly identifiable to the budget and

○ funding process. The Maintenance Program prepared by AFLC schedules contractor or depot level maintenance and modification for aircraft/missile/ground equipment not in the Modernization Program. All modification labor, maintenance labor, and locally purchased materials are funded from the Air Force operation and maintenance (O&M) budget program. (4) The Modernization Program prepared by AFLC/AFSC and directed by HQ USAF modernizes a specific system or equipment item. The program is accomplished with modification funds. (4)(5)

○ Simply defined, a modification is a change in the physical configuration or in the functional characteristics of a system or equipment. Five modification classes have been established, each with a specified level of management as the approving authority. Classes I, II and III are either temporary and necessary to accomplish a special mission or purpose, or are not applicable to operational systems and equipment. Class IV modifications are made to (1) insure safety of personnel, systems or equipment, (2) correct equipment deficiencies, or (3) improve logistic support. Class V modifications provide a new or improved operational capability to the system or equipment. (6) A Class IV modification requires HQ AFLC approval. However, if a Class IV modification has a projected cost of five million dollars or more in any single year, it must also be approved by HQ USAF. HQ USAF must approve all Class V modifications.

○

The research in this thesis is directed at Class IV modification programs on aircraft which required HQ USAF approval. These modifications are part of the AFLC Modernization Program for aircraft.

### Significance of the Problem

There are a number of significant reasons for conducting research on this problem; two are presented. First, national objectives and the domestic and foreign policies adopted by the United States Government are predicated in part on the ability of the Government to call upon specified military forces when required. An unfavorable cost outcome, on one or more DOD programs, results in a reprogramming of funds. It can also result in cancellation of programs, cutbacks in production schedules and require further reliance on aging weapons and equipment. (7:7)<sup>a</sup> The ability of the Government to carry out its policies is thereby weakened. Funds used by DOD for weapon system procurement in excess of that required to support Government policy are unavailable for other purposes and programs, domestic or foreign. Second, because of the significant dollar amounts involved in military research, development, procurement, operation and maintenance, any improvement which offers

---

<sup>a</sup>The first number refers to the bibliography listing; the second to the specific page.



( ) a small percentage increase in efficiency portends a potentially large dollar savings. Maintenance, modification and modernization programs do not exhibit the glamor nor significant dollar figures of a C-5A or F-111 program, but the similarity in nature of the procurement process and its detailed activities is striking. The individual program and annual aggregate dollar amounts involved are not to be taken lightly either.

O One concluding thought on the significance of this research is in order. The military-industrial complex is not the evil spectre the mass communications media has portrayed it to be. Neither is it a perfect blending of industry and Government; many shades of gray exist. Hopefully, this research can stimulate further understanding and research; research which is objective and scientific in nature. Research can lead to an even better procurement process. The result will be a more effective and efficient Government and military organization, both as viewed from the United States and abroad.

#### The Need for Research

The General Accounting Office believes that one of the most important causes for cost growth is starting the acquisition of a weapon system before it has been adequately demonstrated that there is reasonable expectation of successful development. (8:2)

Secretary of Defense Laird said, 'The largest single cause of cost growth is over optimism in original cost estimates.' (7:79)

An industry representative states, '. . . many of the recent and highly publicized overruns are rooted in a basic flaw in government policy. Specifically, the Government does not recognize the softness of the technologies used in these systems, and tries to award and administer contracts as though the technology were well in hand and no unexpected problems could possibly crop up.' (9:119)

'. . . political winds as much as military decisions affect this process very much . . .' and 'the political-economical position' were some of the reasons advanced by an industrial research journal. (10:35)

This diversity of expert opinion on the causes of program cost outcomes was in part responsible for the undertaking of this research. The need for research on this problem was verified by the following statements from publications of the RAND Corporation and the General Accounting Office, two of the more knowledgeable groups on defense procurement affairs:

The research indicates the need for continuing efforts to control the cost, schedule and article performance outcomes of programs and for better understanding of the causes for program growth. (11:Abstract)

The scope of our review did not permit a complete identification of fundamental causes of cost growth. The work we did accomplish, however, convinced us that the data brought to light through the SAR we reviewed were insufficient to provide DOD with precise causes for this cost growth. (8:22)

The need for research in AFLC on this problem was in part generated by Mr. Solomon Arnovitz, Chairman, Office of the Procurement Committee, HQ AFLC. His belief in improving the AFLC procurement process through independent, objective research led to permission and sponsorship of this work in the Air Force Logistics Command. He too, was seeking an answer to the question "What causes cost overruns?" AFLC interest centered on large dollar value modification/modernization programs. A cursory review of the available literature on this question indicated some conflicted, some complemented and some duplicated. Some conclusions seemed incorrect; others accurate only in part. As a total picture, it presented a confusing scene to the manager or person making daily decisions on procurement matters.

The urgency of this need for further research has been accentuated by continuing cutbacks in military spending, particularly defense procurement. The effect of the continuing budget constraints, when combined with the increasing costs of new weapon systems, has been twofold: (1) a reduction in the size of the active aircraft/missile inventory, and (2) tighter budgetary controls on all programs. Thus, in coming years greater reliance will be placed on modernizing and upgrading existing systems, especially if cost overruns of any magnitude occur in the procurement of new systems. Also, with strict

allocation and budgeting of dollars for the selected modification programs, cost growths and overruns in one can only trigger a cascade effect in the others as money must be continually reprogrammed.

### On the Cost Growth Phenomena

The outcome of a defense program or contract is the effectiveness of the program or contract in attaining its intended technical, schedule and cost objectives. This work concentrates on the cost outcome, for as will be shown later, cost may be described as a function of technical performance and schedule. This research seeks to understand and explain why a cost estimate increases or 'grows' over time, why some programs do not incur a cost growth, or even why the final cost may be less than the earliest initial estimate.

### Evolution and Definition

Cost growth is the subject matter of this research and a precise definition is required. The literature and communications media are not precise. The terms: contract growth, contract overrun, cost overrun, cost increase, cost growth, cost estimate growth, program cost growth, price increase and miscellaneous others are often used interchangeably. The misuse of terms and lack of standardization has led to misunderstandings

and communication difficulties, as well as making comparisons of available research work and studies difficult. For example, the works of Belden (12) and Fisher (13) on incentive contracting are not directly comparable because of different definitions of the term 'Overrun &' (12:93); while Lorette (14) shuns the use of the term overrun, building a case instead for 'cost estimate growth.'

Internal Air Force studies have not been consistent either, thereby further adding to the confusion, especially among the working personnel. Definitions used in four Air Force studies, which will be referred to later, are stated to exemplify what constitutes a large part of the problem, lack of clear communications.

From a study performed by the Comptroller of the Air Force (15):

Contract Cost Growth - The difference between the original target price of the contract and the actual (or estimated) price of the contract at completion. For the purpose of this report, the target price of the initial definitized contract is used as the baseline for measuring cost growth.

Contract Cost Overrun - The difference between the actual price of the contract at completion and the target price as adjusted from the original target price.

From a study performed by DCS/Systems and Logistics, HQ USAF (16):

Program Cost Overrun - A condition whereby the original estimated program costs are exceeded and the submission of a revised Form 440 (Class V Modification Feasibility Study) is necessitated.

Contract Cost Overrun - A condition which exists on cost reimbursement type contracts whereby the contractor is unable to complete the work covered in the contract within the estimated amount shown on the contract.

From a later DCS/Systems and Logistics, HQ USAF, study (17):

Contract Cost Overrun - A condition which exists on cost reimbursement type contracts whereby the contractor is unable to complete the work covered in the contract within the estimated amount shown on the contract.

Over Target Cost - A term applied to fixed price incentive contracts. It occurs when the final contract cost (price) exceeds the "target Price" specified in the contract.

Program Overrun - When the expenditures for a program exceed the total dollars authorized for a specific program which in turn affects the budget.

Cost Growth - This represents two types of cost which are not a contract overrun or over target cost but does impact the final contract (or program) cost to the Government. These are:

- (1) Negotiated adjustments (including termination) made to the basic contract cost because of a change in scope of work.
- (2) Adjustments made, if provided for in the contract, for abnormal fluctuations in the economy, changes in law impacts, and formula adjustments . . .

From a HQ AFLC letter (18) summarizing an internal study on modification cost estimates (19):

A cost overrun is the inability of a contractor to perform cost or incentive type contractual arrangements at an established price. Cost growth however, is attributable to agreed upon changes, additions or re-design of original equipment.

It must be noted that these studies were conducted in a time period when "cost overruns" were receiving national attention, and uniform, standardized definitions were non-existent.

The phrase 'cost overrun' has been used for many years by Federal procurement personnel. In the last few years, and in particular since the 1968-1969 Congressional hearings on The Economics of Military Procurement (20), considerable public attention has been focused on this phrase. Because of the intense public scrutiny, its shortcomings were highlighted and the need for a more descriptive and accurate phrase recognized. The new phrase used by DOD is 'cost growth.'

Evolution of the term cost overrun into cost growth is traced by Mehl (21) through 1969. By this time an Ad Hoc Committee to more adequately define the term 'cost overrun' had been established by the Assistant Secretary of Defense (Installations & Logistics). By October 28, 1969 the committee had developed the term 'cost growth' and structured a set of nine related definitions, called cost growth change categories. The new definitions were distributed to the various agencies of DOD under a cover letter from Deputy Defense Secretary Packard on November 26, 1969. (21:10) The definition of 'cost growth' as it appeared in this memorandum was:

Cost Growth is a term related to the net change of an estimate or actual amount over a base figure previously established. The base must be relatable to a program, project or contract and be clearly identified including source, approval authority, specific items included, specific assumptions made, date and amount. The events causing 'Cost Growth' must then be explained by one or more of the following categories and the appropriate amount of each shown as 'estimated' or 'actual.'

The nine categories set forth in the memorandum were:

1. System Performance Change
2. Engineering Change (Not Affecting Performance)
3. Quantity Change
4. Contract Added Support
5. Schedule Change
6. Unpredictable Change
7. Economic Change
8. Estimating Change
9. Contractual Price Adjustment

These nine categories with their same definitions appeared in Enclosure 1 to Department of Defense Instruction (DODI) 7000.3, December 19, 1969. Program cost variance analysis for the Selected Acquisition Reports (SAR) was to "be explained in terms of" these categories. (22:6-7)

Based on experiences gained in using these definitions to accomplish the Selected Acquisition Reports, changes were formulated. By June 22, 1970 new definitions of cost growth and the categories had been established. These definitions were issued as an attachment to a Memorandum from Deputy Secretary of Defense Packard



on August 5, 1970. (23) The new definition of cost growth was:

Cost Growth is the net change of an estimated or actual amount from a base figure previously established. The base must be relatable to a program, project, or contract and be clearly identified including source, approval authority, specific items included, specific assumptions made, date and amount. The events causing 'Cost Growth' must then be identified by one or more of the following categories and the appropriate amount of each shown as 'estimated' or 'actual.' These categories do not necessarily determine whether the cost growth could have been avoided by the Government or contractor or both. They provide the essential visibility and information required to determine the cause of the cost growth.

Other than minor word changes in the first sentence, the only change was to add two qualifying sentences. Changes were also made "to improve the clarity of the categorization of the reasons for cost growth." (23) There were still nine categories, but they were not the same. The new change categories were:

1. Engineering Change
2. Quantity Change
3. Support Change
4. Schedule Change
5. Unpredictable Change
6. Economic Change
7. Estimating Change
8. Contract Performance Incentive
9. Contract Cost Overrun (Underrun)

The categories and their definitions as stated in the memorandum are identical, except for Cost Overrun (Underrun) which is more detailed, to those used to classify

cost variance analysis in the revised DODI 7000.3, Enclosure 1, of June 12, 1970. (24:7) The definition of these terms may be found in Appendix A under Cost Growth Categories.

The importance of the definitions and categories is made clear by recalling the confusion which existed before their publication, and by the following quotes from the Packard Memorandum (23):

This definition for 'cost growth' or 'cost decrease' will be used when necessary to explain programs, budgets or contracts. . . . It is expected that this 'cost growth' definition will be used whenever appropriate in management reporting, testimony, official correspondence or speeches, to explain instances of cost growth.

Much effort, thought and coordination went into the above definitions. They are also 'official' definitions. Therefore, these latest definitions will be used or referred to in the remainder of this research. Concerning these definitions and instructions, two critical notes will be made. First, although 'cost growth' may be a descriptive and appropriate phrase for some programs, projects or contracts, the term does carry a stigma. Unfortunately, one is prepared for only cost growths. Perhaps the term "cost variance" or "cost outcome" would have been better. Second, and the more significant comment, is that the nine categories are not 'causes' of cost growth. This comment is discussed at length in the next subsection.

### Causes or Categories

The absence of official definitions for cost overrun created a void which led to confusion and misunderstanding. A similar event appears to be occurring now with the 'causes' of cost growth. The nine cost growth categories are frequently being referred to as the causes of cost growth. This is not surprising if an examination is made of some official correspondence on the subject.

From the definition of 'cost growth' (23):

The events causing cost growth must then be explained by one or more of the following categories and . . .

From the definition of 'cost overrun' (24:9),

(Appendix A):

. . . but not attributable to any other cause of cost growth as previously defined.

The nine cost growth categories are just that; categories and not causes. Webster defines 'cause' as, "a person, thing, fact or condition that brings about an effect or that produces or calls forth a resultant action of state." (25:356) Although one can argue that these categories fit this definition, they are not first causes. It is toward first causes that one must work to remedy any deficiency.

For example, cost estimates were received and procurement action started for the modification of 400 USAF C-130 aircraft (Appendix B). Two years later the quantity to be modified was increased to 460 aircraft. The categorization of the cost growth can be 'Quantity Change,' but it is not the cause. The question that needs to be asked is, "What caused the quantity to be increased that amount at that time?" The cause of the cost increase could be that subsequent engineering tests showed other model aircraft would experience the same problem and therefore need the modification also; or, that inclusion of 60 additional, newer model aircraft initially could jeopardize commencement of the modification program because of funds availability or the additional justification required.

The danger, in treating categories as causes, is the misunderstanding that can result, as well as the possible misdirection and misapplication of resources to correct past mistakes or avoid future cost growths. The value of the cost change categories and their definitions lies in their official structure and serves as a base for getting to root causes.

#### Studies and Data

The weapon system research, development and acquisition process has been the subject of numerous articles,

speeches, studies, investigations, hearings and books in recent years. In fact, this vast amount of literature: some good, some bad, some factual, some biased and some opinionated, has merely served to heap confusion onto an already complex, interrelated process. With the exception of the work of Peck and Scherer (26), the majority of publications on the acquisition process has dealt with selected facets of defense procurement, such as contract types, price estimating techniques or profit policies.

The problem of cost growth and overruns is neither new nor peculiar to the military. (27:2) Yet, only recently have studies concentrated on understanding the 'whys' of program and contract outcomes. Some of the early, more quotable studies were by Marshall and Meckling (28), Peck and Scherer (26), and Summers (29); later works of note were by Marschak (30), Lorette (14), Perry, et al. (11), the Air Force Comptroller (15), and the AFSC Directorate of Procurement Support (31). Through the SARs (24), additional information on outcomes is being compiled for DOD data banks. Other studies and data sources are also available. Reference Appendix D.

All these referenced studies have a number of features in common. All relate to the research, development and/or production of new major Air Force weapon

systems. All discuss in some fashion contract or program outcomes. All offer thoughts, suggestions or recommendations for improvement of the process. Each has added to or complemented the other. To summarize the review of literature available on this topic:

1. Research efforts have focused on major weapon systems development and acquisition.
2. Many of the major characteristics, factors and difficulties associated with the weapon system acquisition process have been isolated and discussed for years.
3. Extreme care must be exerted when referring to or comparing these studies, their results and recommendations because of differences in assumptions, definitions, data bases and adjustments.

From this initial literature review three items appeared quite striking: first, the lack of general research, studies and data on procurement outcomes dealing with large modification programs; second, the similarity in the process between acquiring major new systems and performing major modifications on existing systems; and third, the lack of the system approach to procurement improvements.

### CHAPTER III

#### PROCESS ANALYSIS

Anyone who thinks he completely understands the situation simply does not know all the facts.

Anonymous

This chapter discusses the search for literature and data relating to cost growths on AFLC modification programs and the results of this search. It also describes the 'why and how' of the two modification program case histories which appear as Appendices B and C to this thesis. Permission and sponsorship of this research was through HQ AFLC, DCS/Procurement, Brigadier General A. J. Dreiseszun and Mr. Solomon Arnovitz. Visits were made to HQ AFLC at Wright-Patterson AFB, Ohio to obtain information and data throughout 1970. Visits were also made to the Warner-Robins Air Materiel Area (WRAMA), Georgia and to the Oklahoma City Air Materiel Area (OCAMA), Oklahoma in this same time period to gather data for the case histories.

#### Literature and Data Search

A comprehensive search for data and studies related in any fashion to cost growth on modification

programs and their associated contracts was conducted. At HQ AFLC, WRAMA and OCAMA personnel at varying levels of responsibility in the Comptroller, Materiel Management, and Procurement and Production organizations were queried to ascertain if any such information was available. The search yielded the following results:

1. Four internal Air Force studies had been conducted: three (16)(17)(19) were noted earlier in the subsection, Cost Growth-Evolution and Definition, the fourth was a special case study of the C-119 Gunship, Class V Modification Program.

2. No data bank existed at HQ AFLC for completed contracts similar to the AFSC Contractor Performance Evaluation Program from which AFSC drew data for its study (31:1); detailed contractual data and summaries were only available at the AMA.

3. The amount of documented program information at HQ AFLC was limited and usually reflected only the present or near present program posture. Detailed tracks of cost, schedule and performance could be found only at the responsible AMA.

4. A reexamination of the open literature emphasizing maintenance and modifications uncovered three related RAND reports (32)(33)(34).

An expansion of these findings is necessary before implications can be drawn. The internal Air Force



studies covered a wide range of topics. The original DCS/S&L study (16) examined four Class V Modification Programs, two each from AFLC and AFSC, which had exceeded original cost estimates. The two AFLC programs were the C-119G/K Gunship (WRAMA) and the SEAOR-55 (SMAMA). The expressed purpose of this study was "to determine the reasons for these program overruns, and recommend a means of eliminating the overruns." (16:2) The later DCS/S&L study (17) was a review of six weapon system acquisitions and three major modification programs, involving fifty contracts, to "determine the correlation, if any, between the method of procurement used, type of contract selected and program success." (17:3) The major acquisition programs were the responsibility of AFSC, while the three modification programs: the Class V SEAOR-62 (SMAMA), Class V C-119G/K Gunship (WRAMA) and the Class IV C-130 Center Wing (WRAMA), were under AFLC. The AFLC Modification Cost Estimate Study (19) was aimed at improving cost estimating and cost tracking of modification programs exceeding \$100,000. Each AMA was requested to conduct a thorough study of this subject. Results and recommendations for improvement were to be made to HQ AFLC. The findings and conclusions of these Air Force studies will be integrated into later portions of this thesis.

The decentralized Air Force approach to procurement and the functional organizational structure of AFLC combined to increase the difficulties of investigating cost growths on large modification programs, especially when more than one contract was involved or programs interfaced or dovetailed. For large modification programs, and particularly for Class V and HQ USAF approved Class IV programs, no central file existed to obtain the big picture at HQ AFLC regarding the cost/schedule/performance aspects of such programs. Once these modifications are approved by HQ USAF and a Modification Program Directive (MPD) issued (5:4), any "net (cost) increase exceeding \$200,000 or 20% of the total approved modification cost, whichever is less" (6:12) requires the approval of HQ USAF. For a Class IV modification, documentation of this increase appears on the AFLC Form 48, Configuration Control Board (CCB) Item Record, which is processed through the AMA and the AFLC CCBs. The "reasons for the increase and recommendations for remaining within the authorized funds by stretching out the program, reducing the number of units to be modified, etc." (6:12) are to be included. For the modification programs investigated this was the only required written documentation for justifying program cost increases.

The referenced RAND reports were written in 1963-1964. Deavers and McCall (32) presented a method for

analyzing and aiding the decision-making process related to procurement and product improvement, where "procurement refers to the technical procedures used to acquire a new weapon system" and "product improvement refers to the process of modifying existing weapon systems to meet a newly defined mission, or to correct an operational or logistic deficiency." (32:2) Their work is significant since they are harbingers of a major concept in this research, namely, "Procurement and product improvement are so closely related that a single analytical framework can be used for both types of decisions." (32:43) Although Sweetland (34) was primarily concerned with assessing the effectiveness of a weapon system modification, his work notes the lack of complete cost data, areas of costing a modification that must be considered, and provides two program examples: an Air Training Command power plant modification of all T-38A aircraft, costing over \$17 million; and an Air Defense Command fire control modification of F-101 aircraft, whose engineering and kit cost alone were \$21.9 million. (34:2) Deavers (33) addressed the problem of selecting product improvement candidates. In so doing, he developed a listing of data needed to determine whether a proposed product improvement is economical. (33:23)

The implication of these findings can be summarized as follows:

1. Past studies provide a meager platform from which to depart on a current study of cost outcomes on modification programs. Their different aims lead to different technique and mixed results.

2. Without the available data base one can not study cost outcomes and causes utilizing statistical tests for significance. To acquire the necessary data would require an extensive, in-depth probe of numerous modification programs and/or the use of survey techniques.

Based on all considerations stemming from the literature and data search, the following hypothesis was formulated: Large modification programs requiring HQ USAF involvement exhibit the basic characteristics of major weapon system acquisitions. If this hypothesis is true, then to a large degree, research and findings on the procurement process for major acquisitions can be applied to the procurement process for modification programs, and vice versa. The next section details the research to support this hypothesis and to examine modification programs in detail with a view toward cost growth and its causes. Emphasis is placed on the program-history method: the compilation and analysis of intensive case histories of modification programs.

### Case Histories

The description of the DOD and Air Force process for procurement of major weapon systems stems from a long list of DOD and Air Force directives, instructions, manuals and regulations. For a description of this process from an industrial point of view, reference the Aerospace Industries Association study (35) and the article by Drake (9). For an Air Force/academic viewpoint see Lorette. (14) Basically, there are four phases to this process: (1) Concept Formulation, when program objectives are identified and development plans conditionally approved, (2) Contract Definition, when objectives are reduced to firm specification as confirmation of the design decision to proceed, (3) Engineering Development, when the equipment is developed and tested, and (4) Production and Operation, when the system is produced and deployed. These phases can also be broken down into six project segments: system concept, system definition, system design, system development, fabrication-assembly-test, and operation-support. See Figure 1. Case histories documenting major weapon system programs are plentiful and are included in many of the previously referenced studies. One can readily superimpose the four phases or six project segments over any of the case histories. No similar, well-documented case histories could be found for major modification programs, however,

# PHASES

Preacquisition		Acquisition	
Concept Formulation	Contract Definition	Engineering Development	Production Operation

# SEGMENTS

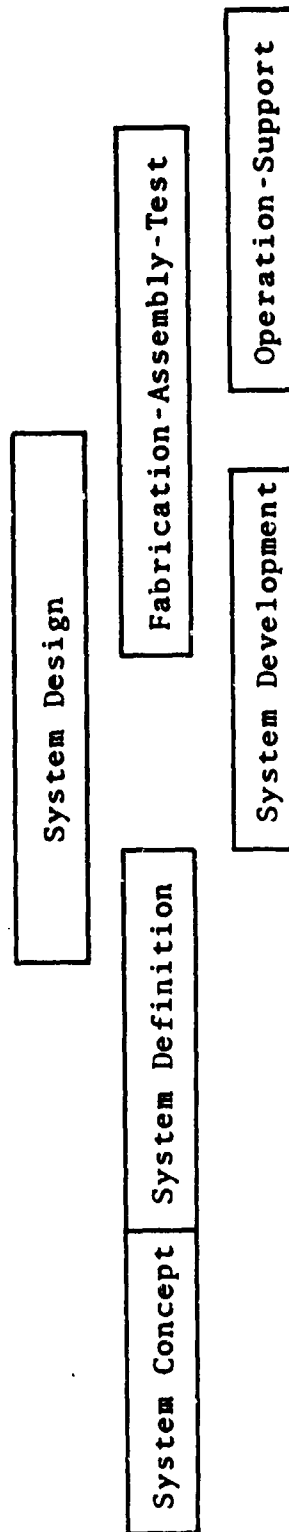


Figure 1. The Procurement Process: Phases and Segments.

there were abbreviated program histories in some of the previously referenced literature. Also, these references yielded statements to support the hypothesis. In the Deavers and McCall study their first main conclusion was:

Procurement and product improvement are so closely related that a single analytical framework can be used for both types of decisions. The information and analysis needed for efficient procurement is essentially the same as that required for product improvement. But, more important, the joint analysis immediately reveals that the two activities can be treated similarly. (32:43)

The DCS/S&L study stated:

SPO personnel interviewed at ASD indicated that the quick-response nature required of this type of Class V Modification lent itself to the same functions and management actions of a complete weapon system SPO, but in somewhat more abbreviated steps or compressed time cycle and in an atmosphere of great urgency. (16:6)

Then concluded:

The manning of all disciplines such as data, configuration, reliability and maintainability, test and development and logistic support is just as essential in a Class V Modification Program as it is on a complete weapon system development and acquisition program. The above must be accomplished in a compressed time frame of a Class V Modification. (16:6)

To verify that HQ USAF approved and directed Class IV modifications demonstrate characteristics similar to major system acquisitions and to investigate in detail

the current procurement atmosphere, two case histories were compiled. The method of program selection, data collection and analysis follow as subsections. Two statements from Marschak (30) also represent the position of this researcher on case histories.

Project histories. . . have several serious limitations. The main one is that a strong subjective element often enters the interpretation of a history and the decision as to whether or not it supports a given conjecture. (30:49)

. . . a strong word of caution is in order about the interpretation of the histories. The criticism of past . . . procedures, or the past performance of any . . . agency, is not our purpose. . . . Any such interpretation of the histories entirely misses the point: to illustrate an important method for acquiring knowledge about the . . . process. (30:50)

#### Program Selection

The section titled, The Procurement Process, noted that systems and equipment were segregated according to aircraft, missiles, and other, along lines identifiable to the budget-funding process. Modifications to USAF aircraft are funded under Budget Program (BP) 110000, Appropriation 57X3010 (Aircraft Procurement, AF); missile modifications under BP 210000, Appropriation 57X3020 (Missile Procurement, AF); and vehicle, electronic and telecommunications, munitions, etc. are funded from Appropriation 57X3080 (Other Procurement, AF).



Table 1 shows the USAF approved modification dollar breakout for AFLC for Fiscal Years (FY) 1968, 1969 and 1970 for three of the major modification Budget Programs.

Table 1  
AFLC Modification Budget Program Accounts<sup>1</sup>

	FY 1970 <sup>2</sup>	FY 1969	FY 1968
BP 110000	\$303,583	439,366	511,027
BP 210000	3,000	35,892	34,655
BP 880000	----- <sup>3</sup>	29,118	20,661

Note 1. USAF Approved, in thousands of dollars.

Note 2. Incomplete, as of June 1970.

Note 3. Not available.

Source: HQ AFLC (MMRER).

Because of the predominant dollar amounts in BP 110000, it was decided to examine aircraft modification programs. By examining only one category, aircraft, to be taken from different AMAs, comparisons could be made. Active, unclassified aircraft modification programs in the \$60-\$100 million range, free of legal-political complexities were sought. Such programs would permit research which: (1) involved significant dollar amounts, (2) could be accomplished in a reasonable period of time, and (3) could be

published in open form. Discussions with HQ AFLC personnel to find such programs resulted in selection of the following two programs:

1. The C-130 Center Wing Class IV Modification directed by Warner-Robins Air Materiel Area (WRAMA) and performed by the Lockheed-Georgia Company.

2. The B-52 G&H Stability Augmentation System Class IV Modification directed by the Oklahoma City Air Materiel Area (OCAMA), having kits manufactured by the Boeing-Wichita Company and other vendors, and installed at Oklahoma City and San Antonio AMAs.

Programs were sought which appeared to exhibit some growth in costs over a period of time; there were a number of programs which did not meet this condition.

#### Data Collection

Information for the case histories came from two basic sources: record/file reviews and personal interviews. After the programs were selected, reviews and interviews were conducted at HQ AFLC. The focal points of the HQ AFLC review were the aircraft modification program funds monitors and the program technicians in the Directorate of Materiel Management (MM).

Trips were made to WRAMA, Georgia, 31 August-4 September 1970, and OCAMA, Oklahoma, October 15-22, 1970 to obtain data available only at the AMA. Each visit

was planned and coordinated beforehand through the Directorate of Procurement and Production (PP) at the respective AMA. During these visits official contract files were made available in PP as well as interviews allowed with the respective Contracting Officers, buyers and pricing personnel. Personnel from the System Support Manager (SSM) in MM made available program documentation and were interviewed. Service Engineering, Comptroller and History offices were also visited. Follow-up communications, telephonic and written, filled in missing data links.

Based on these reviews and interviews, case histories for each program were compiled. Verification of the histories was obtained by sending them to HQ AFLC in December 1970 for review. These histories form Appendix B and Appendix C to this thesis.

### Program Synopses

The C-130 Center Wing Program was conceived to permanently eliminate fatigue cracks in the center wing section of C-130 aircraft. Under a HQ USAF directed Class IV modification, a new center wing box beam is fabricated and installed in C-130 aircraft by the Lockheed-Georgia Company at its plant in Marietta, Georgia. Reference Appendix B. When the modification program was 'sold' to HQ USAF in April 1968, the estimated cost to modify 400 USAF C-130B/E aircraft was

\$77.8 million. This figure included a fatigue test program, over and above work, and a modified landing gear; the first aircraft was to be input to Lockheed during the first quarter of FY 1969. With a flow time of 21 work days per aircraft the program would be complete by the fourth quarter of FY 1971. The September 1970 approved cost figure for the modification of 460 USAF aircraft was \$97.3 million, but this does not include the fatigue test program which is carried separately, nor the landing gear modification which was deleted. The first aircraft was input on November 1968 and output on February 1969. In FY 1969 thirty aircraft were modified with an average flow time of 55 calendar days; the FY 1970 flow time for 185 aircraft averaged 41 calendar days. If the modification is treated as a 'total' program, then a conservative total USAF cost could be over \$130 million for the 460 aircraft. See Table 8B. There are currently 516 aircraft forecasted to receive the modification since U.S. Navy and Coast Guard aircraft have been added to the program.

The B-52 Stability Augmentation System (SAS) Program stemmed from special life studies on the aircraft aimed at improving the airplane's structural life and its aerodynamic and structural stability in severe turbulence. Under a HQ USAF directed Class IV modification an improved stability augmentation system is fabricated

and installed on B-52G/H model aircraft. Reference Appendix C. The modification program was 'sold' to HQ USAF in September 1967 at a cost of \$60.1 million. This cost figure was based on the Boeing-Wichita Company fabricating 288 modification kits and support equipment for \$51.2 million, then combining with depot teams to install the kits, the total combined installation labor charge being \$8.9 million. Kits would be delivered at the rate of 10 in April 1969 and 20 per month thereafter. The first aircraft input to the depot was to be not later than April 1969 and the last input not later than June 1971. The June 1970 cost estimate for this modification was \$69.7 million, but it is not the same program. Because of aircraft attrition, 285 aircraft will receive the modification. The production modification kit is not the same as the prototype kit because of deletion and repackaging of black boxes in the yaw axis electronics and other attendant configuration changes. The quantities of provisioned items are now firm and different from those envisioned at program initiation. The kit buy was split; the first 125 were purchased from Boeing, the remainder direct from the vendors. Installation is being accomplished by AF depot teams only, at OCAMA and SAAMA. Although difficulties were encountered in kit and support deliveries, aircraft schedules were achieved and the last aircraft input is currently scheduled for July 1971.

The above, abbreviated description has merely highlighted the beginning and a current status of each program. Reasons are not provided for 'why and how' the program moved from point to point. Some may be found in the Appendices, others will be discussed later. To quote these figures without this further understanding could be misleading and typical of many cost/schedule/performance commentaries offered today on defense programs. If the reader desires a more detailed synopsis of program cost, schedule and performance, it may be found in the Summary section of each Appendix.

#### The Modification = Acquisition Hypothesis

The case histories support the postulated hypothesis: Large modification programs requiring HQ USAF involvement exhibit the basic characteristics of major weapon system acquisitions. Such modification programs, when considered in their totality, can be segregated into the four phases or six segments of a major system acquisition. The major difference occurs in preacquisition during the concept formulation and contract definition phases. These phases are not as sharply defined and generally are more compressed, since the need is more immediate. For example, in the C-130 Center Wing Program, ten months (Aug 67 - Jun 68) elapsed between the time the seriousness of the wing fatigue cracking

became apparent and the modification contract was awarded. The B-52 Stability Augmentation System (SAS) Program however progressed in a more orderly and identifiable fashion through the phases and segments. Reference Figure C1. Events and segment association are as follows: system concept = B-52 accidents and life studies; system definition = CCP 1195 study; system design and development = prototype program; fabrication, assembly and test = modification program (Mod No 10007); operation and support = return of B-52 to operational use. And, as discussed in Background the contractual aspects of modification programs and major system acquisitions in the Air Force are similar because of ASPR (1) and associated directives and publications. The involvement of HQ USAF completes the comparison. Their role in the decision making process: approval of overall cost, schedule and performance parameters, and changes thereto, is identical to that performed over a System Program Office (SPO) responsible for the management of a major weapon system acquisition.

In summary, a large modification program, Class IV or V involving HQ USAF, is a microcosm of the Air Force weapon system acquisition process and occurs repeatedly throughout the Operation-Support segment of the weapon system life cycle. The categories and causes, studies and data of cost growth applicable to

the major weapon system acquisition process are transferable to major modification programs and vice versa.



## CHAPTER IV

### PROCESS SYNTHESIS

The system upon which this Country now depends for the acquisition of weapons for its military forces is one of the most complex technical-economical-political processes ever evolved. Compounding the problems associated with this complexity are the pressures to reduce the dollars spent for defense, concern over the high cost and cost growth of today's weapon systems and demand for reallocation of national resources. These pressures, concerns and demands have led to intense national interest in the defense acquisition process. (36:5)

This chapter describes a general model of the procurement process and program cost outcome models. The modelling emphasizes the systems approach: the recognition and identification of all factors related to the problem including their dependencies and interaction, in order that available resources may be allocated in an optimum manner (37:1), thereby leading to problem solution or process improvement. New insight into the procurement process and the problem of cost growth can be gained by examination and manipulation of these models.

#### A Model of the Procurement Process

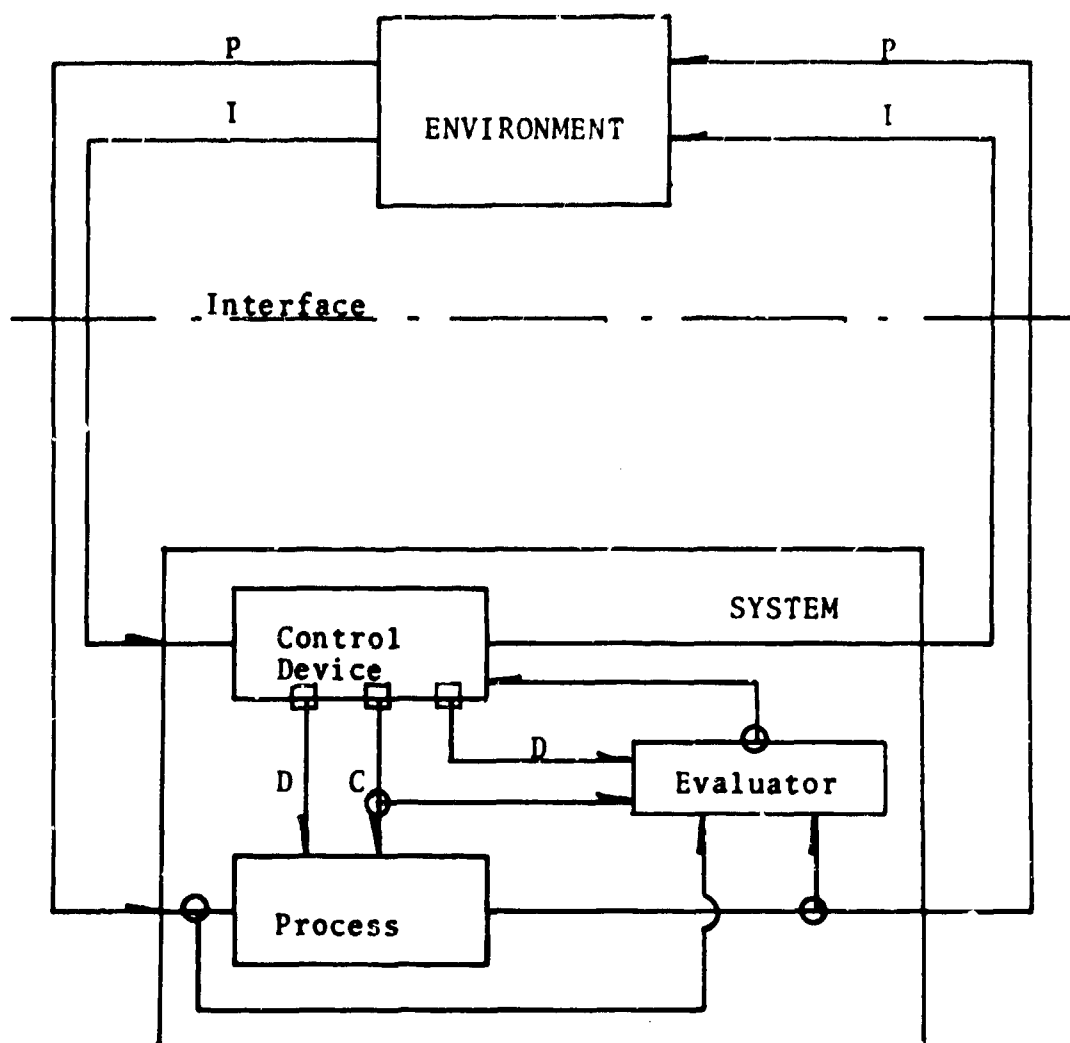
A model of the procurement process can be developed using systems theory. The model presented is an

adaptation of the work of Nelson (38)(39) and Forrester (40).

### Systems in General

To discuss analyzing and improving the performance of a complex system, the physical and decision making aspects of the system must be considered in relation to environmental factors. A system and its environment can be described by a dynamic, closed loop system diagram. A generalized system diagram is shown in Figure 2.

Figure 2 represents the relationship of one system to the total environment. The system is composed of a control device, a process, and an evaluator. The control device makes decisions and generates intelligence based upon information and intelligence received. It makes two basic decisions: decisions on the design of the process and evaluator, and decisions on the control of the process. The system process receives inputs of five types of physical goods: money, material, personnel, capital equipment and orders/requisitions. The output of physical goods from the process is dependent upon the process design and control exerted by the control device. The evaluator, designed by the control device, receives inputs of information regarding physical goods flow rates and levels, process performance and control decisions. The evaluator informs the control



Notation:

P = Physical Flow

I = Intelligence Flow

□ = Decision: D = Design, C = Control

○ = Information Tap

Figure 2. Generalized System Diagram.

device of the overall system performance. Redesign of the process and evaluator and recontrol of the process are accomplished, as determined by the control device, based on intelligence received from the environment and information from the evaluator. Note, that in this one system diagram, the environment acts as a source and sink for physical goods and intelligence.

Intelligence, as used here, is the data and knowledge flowing into the control device concerning the availability (in terms of time, cost, quality and quantity) of physical goods in the environment. It also includes inputs of attitudes, concepts, beliefs, management techniques, and policies occurring in the environment. Observe that the system also outputs intelligence which goes to the environment.

#### The Aerospace Contractor As A System

To aid in understanding of the general model consider this example. Let the system represent an aerospace contractor who designs and manufactures aircraft or modification kits. The control device is contractor management. Assume management has decided that its evaluator will be profit and that the method of aircraft/kit production (the process) has been defined. After a new Government contract (order) has been received, funds (money) begin to flow in from the Government (part of the

Environment). The contractor lets subcontracts (requisitions and money outflows) to the lowest bidder, based on a profit evaluator. Orders also go out for more personnel and capital equipment to perform the contract. Soon material and personnel are flowing in to the contractor's plant. Aircraft/kits are produced and shipped (material outflow). Information on the flows and process performance are sent to the evaluator. The profit figure sent to management (control device) will determine if changes (decisions) must be made in the design or control of the process.

#### A Four System Model

A general procurement process model will now be presented. It is an expansion of the earlier model to allow for inclusion of more systems. The model can also be considered as an extension of the research work of Lorette (14). By the use of a system diagram, dimensionality of flows can be preserved.

Consider a simplified procurement model with four systems: the Using Command, the Government Buying Office, a Headquarters and the Contractor. Reference Figure 3. If the B-52 SAS Program were used as an example, then the systems would be identified as: Strategic Air Command, Oklahoma City AMA, DOD/HQ USAF, and Boeing-Wichita, respectively. The difficulty in graphically

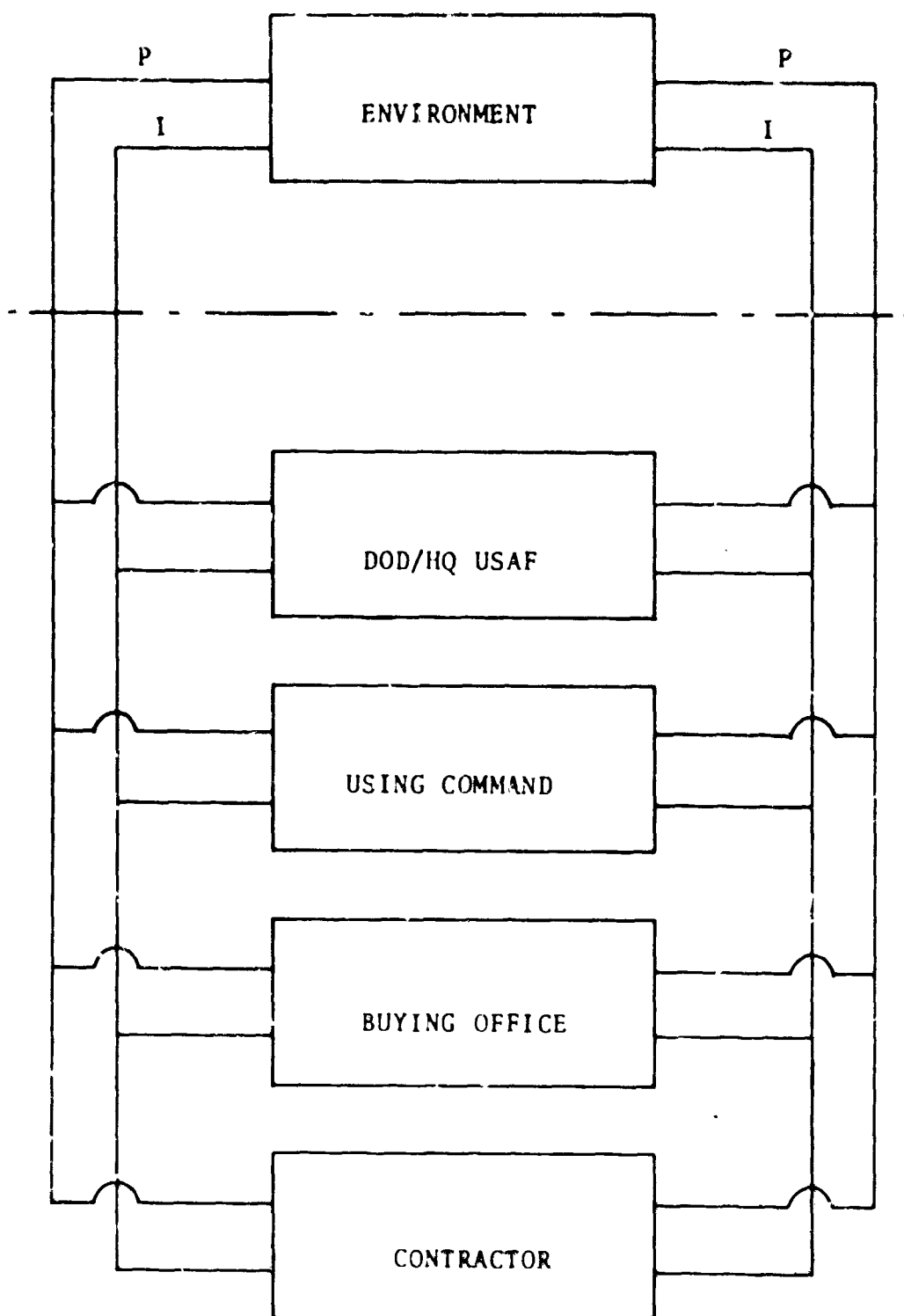
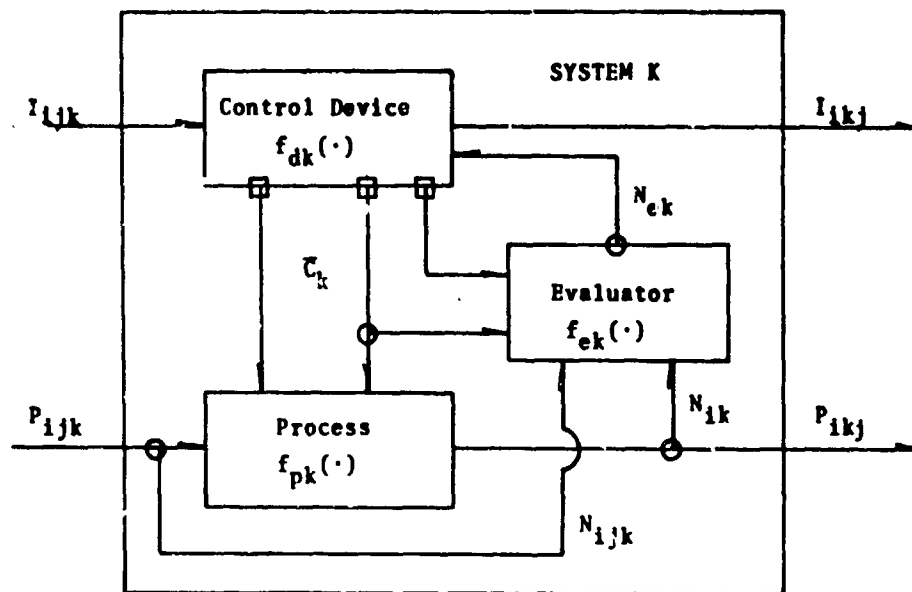


Figure 3. Four System Procurement Model.

diagramming the intelligence and physical flows between each system and the environment becomes obvious even with only four systems; and, no attempt has been made to show information or decision flows within the system or flows among systems in Figure 3. This difficulty can be overcome by the use of matrices and the introduction of related notation. Figure 4 presents a general system diagram with notation and functional relationships for the Kth system.

Table 2 describes in matrix form one possible representation of the physical goods flow patterns which can exist among the systems and environment for the four system model. A blank, or zero, indicates no flow, a one (1) indicates a flow. For example,  $P_{113} = 1$  implies a flow of money ( $i=1$ ) occurs from DOD/HQ USAF (System 1,  $j=1$ ) to the Buying Office (System 3,  $k=3$ ). In a similar fashion flows of intelligence can be evaluated. As an example, say the development of a weapon system by an unfriendly nation poses a new threat. Table 2 also depicts this intelligence flow with the same four systems.  $I_{134} = 1$  implies intelligence on the threat ( $i=1$ ) flows from the Buying Office (System 3,  $j=3$ ) to the Contractor (System 4,  $k=4$ ). Another example of an intelligence flow would be knowledge of fund levels and availability in other systems.



Notation:

$f(\cdot)$  = function

$f_{pk}$  = process function of kth system

$f_{ek}$  = evaluator function of kth system

$f_{dk}$  = decision function of kth system

=  $\{f_{d1k}, f_{d2k}, f_{d3k}, f_{d4k}\}$

$I_{ijk}$  = intelligence flow of ith type from system j to system k

$P_{ijk}$  = physical flow of ith type from system j to system k

$C_k$  = vector of control variables for kth system

$N_{ek}$  = information from kth system evaluator

$N_{ijk}$  = information to evaluator on ith type physical flow from system j to system k

$N_{ik}$  = performance information to evaluator of ith type on kth system

Functional Relationships:

$$I_{ikj} = f_{d1k}(I_{ijk}, N_{ek})$$

$$f_{pk} = f_{d2k}(I_{ijk}, N_{ek})$$

$$N_{ek} = f_{ek}(C_k, N_{ijk}, N_{ik})$$

$$f_{ek} = f_{d3k}(I_{ijk}, N_{ek})$$

$$P_{ikj} = f_{pk}(P_{ijk}, C_k)$$

$$C_k = f_{d4k}(I_{ijk}, N_{ek})$$

Figure 4. Generalized System Representation.



Table 2  
Procurement Model Flows<sup>1,2</sup>

Physical Flows <sup>3</sup> ( $P_{ijk}$ )															
i=1 Money					i=2 Material					i=3 Orders					
1	2	3	4	E	1	2	3	4	E	1	2	3	4	E	
1		1									1	1			
2									1	1		1			
3			1							1	1		1		
4				1		1								1	
E	1							1							

Physical Flows <sup>3</sup> ( $P_{ijk}$ )      Intelligence Flows <sup>3</sup> ( $I_{ijk}$ )															
i=4 Personnel					i=5 Equipment					i=1 Enemy Threat					
1	2	3	4	E	1	2	3	4	E	1	2	3	4	E	
1		1	1	1	1						1	1	1	1	
2	1		1	1	1			1		1			1		
3	1	1		1	1								1		
4	1				1		1		1						
E	1	1	1	1				1		1	1				

Note 1. System 1 - DOD/HQ USAF  
System 2 - Using Command  
System 3 - Buying Office  
System 4 - Contractor  
E - Environment

Note 2. Only flows pertinent to the program under contract are considered.

Note 3. k = abscissa, j = ordinate.

The interpretation of the generalized system representation for the aerospace contractor ( $k=4$ ) would be as follows:

1. Recall that in the earlier example, the control device was contractor management, the process was aircraft/kit production, and the evaluator was profit.

2. Management determines system design and control with its decision function  $f_{d4}$ , a vector function of four functions:  $f_{d14}$ ,  $f_{d24}$ ,  $f_{d34}$ , and  $f_{d44}$ .

3. The contractor decision function ( $f_{d4}$ ) determines intelligence outflows ( $I_{i4j}$ ), the evaluator function ( $f_{e4}$ ), the process function ( $f_{p4}$ ), and the control variables ( $\bar{c}_4$ ) based on intelligence inflows ( $I_{ij4}$ ) and evaluator information ( $N_{e4}$ ). Consider this simple example. Assume at time  $t_0$  the information from the evaluator,  $N_{e4}$ , is a measure of profitability, return on sales. Based on new market intelligence, contractor management (the control device) makes a design decision ( $f_{d34}$ ) to change the measure of profitability to return on assets at a later time  $t_1$ . Then

$f_{e4}(t_0)$  = Function which converts input data to provide a measure of profitability, return on sales.

$f_{e4}(t_1)$  = Function which converts input data to provide a measure of profitability, return on assets.

4. Physical outflows ( $P_{i4j}$ ) are determined by the process function ( $f_{p4}$ ) acting on physical inflows ( $P_{ij4}$ ) in accordance with the vector of control variables ( $\bar{c}_4$ ).

Each of the other three systems can be visualized in the above manner. The major components of these systems at some time  $t_i$  might be as follows.

System 1 - DOD/HQ USAF

Control Device: Management  
 Process: Headquarters organization  
 Evaluator: USAF military readiness

System 2 - Using Command

Control Device: Management  
 Process: Air cargo movement  
 Evaluator: Costs (\$/ton-mile)

System 3 - Buying Office

Control Device: Management  
 Process: Equipment procurement  
 Evaluator: Budget goal realization

Further Expansion of the Model

The use of the generalized systems representation and matrices permit growth of the procurement process model to the extent desired. Other systems could be broken out of the environment. Examples of systems which could be added to make the model more complete are Congress, subcontractors, the public, industry in general, and the Administration. The effect of these additional systems on cost outcomes could be examined

through the changed functional relationships and modified matrices.

Consider the addition of the public and Congress to the model. The public, as a system, would be recognized as a source of intelligence which flows to Congress and the aerospace industry. If industry obtains sufficient intelligence flows from the public and Congress on their attitudes toward pollution and ecology, then management may redefine its process, e.g., reprocess waste material rather than dumping. This could result in an increased, allowable overhead charge to Government contracts, to wit, cause a cost growth. The model could also explain the degree to which Congress affects the procurement process through its control over procurement authorizations, appropriations, and legislation.

#### In Review

The model was developed to fill a need. In the course of the literature search it became obvious that if one was to attempt to make sense of the literature, a framework, a description of the process, was needed. No such description could be found to order and explain the myriad of reasons offered as causes of cost growth.

The model is crude; it is a start. It is believed that it can serve anyone interested in the

procurement process to relate and put into proper perspective, that which is being written and spoken. Consider the following three examples.

1. Lorette (14) describes the pressure exerted on the SPO (Buying Office) by the Using Command, which has no financial responsibility, to incorporate 'gold-plating' Engineering Change Proposals (ECPs) suggested by the Contractor. To describe this pressure Table 2 would show no money flow ( $i=1$ ) from System 2, the Using Command, but order flows ( $i=3$ ) from System 2 to System 3, the Buying Office. If an intelligence flow matrix were made on contractor brochuremanship and sales pitches, then it would show a flow from System 4, the Contractor, to System 2, the Using Command.

2. Proxmire (41) describes the exchange and flow of personnel between DOD/USAF and industry as a cause of cost overruns. This phenomenon would be shown in Table 2 under personnel flows ( $i=4$ ). However, to determine if it in fact had an effect on cost growth, it would be necessary to examine a number of intelligence flows.

3. If the contractor 'buys-in,' this could be represented by an intelligence matrix on funds status. It would show that the contractor knows the availability of dollars at DOD/USAF for this program, or he has favorable intelligence on the attitude of the buyer or Headquarters to permitting add-on changes. Other

possibilities for the buy-in could be explained by the model. It could show if the contractor has decided to define his evaluator as growth in lieu of profit, or that the contractor lacks control of his estimating process.

In conclusion, the procurement process should be viewed in its totality. A systems approach should be taken. By considering it as a blending of systems which interact, with each other and the environment, a better comprehension and appreciation can be gained into why program cost outcomes are different from earlier estimates.

#### Mathematical Models

What constitutes a modification program, and how much does it cost? To understand the cost growth phenomenon, these questions need be answered. As used in this thesis, a modification program encompasses all actions taken by the Air Force and the associated industrial contractors to translate a required operational capability or an operational deficiency into a viable change on equipment or systems currently in the Air Force inventory. The modification cost is the cost to the Government to accomplish these actions.

$$MPC = \sum_{i=1}^2 \sum_{j=1}^4 C_{ij}$$

where

MPC = Modification Program Cost

$C_{1j}$  = Cost of the  $j$ th cost element incurred by the Government

$C_{2j}$  = Cost of the  $j$ th cost element incurred by the Contractor(s) and allowed by the Government

$C_{i1}$  = Development cost element

$C_{i2}$  = Acquisition cost element

$C_{i3}$  = Initial logistics cost element

$C_{i4}$  = Recurring cost element

Also

$$C_{2j} = \sum_{k=1}^{n_j} CP_{jk}$$

where

$CP_{jk}$  = Contract price of the  $k$ th contract or supplies and services in the  $j$ th cost element

$n_j$  = Total number of Government contracts in the  $j$ th cost element

Note that by definition, contract price equals allowed contract costs plus profit or fee. Thus, the cost of a modification program is the sum of the costs for all Government let contracts and Government related activity.

This concept of visualizing the cost of a modification program is an extension of Life Cycle Costing (LCC):

Life Cycle Costing is an acquisition or procurement technique which considers operating, maintenance, and other costs of ownership as well as acquisition price, in the award of contracts for hardware and related support. The objective of this technique is to insure that the hardware procured will result in the lowest overall ownership cost to the Government during the life of the hardware.  
(42:1-1)

For LCC cost element category definitions see the Glossary of Terms.

In present AFLC usage, the 'cost of a modification' is usually given as:

$$MPC' = C_{22} + C'_{12} + C_{23}$$

where

- MPC' = Abbreviated modification program cost
- $C_{22}$  = Contractor allowed acquisition costs
- $C'_{12}$  = Abbreviated Air Force acquisition costs
- $C_{23}$  = Contractor allowed initial logistics costs

The abbreviated modification program cost omits the cost of all contracts to industrial concerns and the cost of certain Air Force activity for studies, research and development, testing, and prototyping necessary for the



manufacture of a production modification kit. It does include the cost of kit installation by the Air Force ( $C'_{12}$ ), if this work is accomplished at the depot. Reference the B-52 SAS Program. However, in general, Air Force incurred costs on modification programs are not recognized. One of these major costs is the cost to manage the program, i.e., the salaries, travel, facility and overhead costs of the HQ AFLC and AMA personnel involved in program management, service engineering, and procurement. Other examples of Air Force costs unrecognized in costing the modification are system or equipment downtime and Using Command training and program activity costs.

That the cost breakout by Air Force and contractor is important in searching for the causes of cost growth can be demonstrated by the following example from Appendix C.

OCAMA prevented the cost of Mod No 10007 from increasing over \$5 million by going direct to Boeing subcontractors for electronic and hydraulic components on the second increment (159) of production modification kits. By furnishing the kits as GFAE direct to the depot, OCAMA did not have to pay Boeing for systems engineering nor the added-on profit and overhead. However, the cost of OCAMA procurement, engineering,

systems and inventory management personnel, with an associated overhead cost, to accomplish this task inhouse was not charged to the modification. These funds come from different appropriations.

The breakout of costs by development, acquisition and initial logistics is also important when studying cost growth. The abbreviated modification program cost represents the visible tip of the iceberg. Without recognizing that a cost can be shifted from one cost element category to another, misleading conclusions can be drawn about why an 'acquisition cost estimate' grows or decreases.

A time milestone ( $T_m$ ) can be defined as an established point in the chronology of a program. There can be at least six major milestones in a modification program.

- $T_1$  = Modification Requirement established.
- $T_2$  = Contractor/AMA Proposal submitted.
- $T_3$  = Modification Program Directive (MPD) issued.
- $T_4$  = Production Program initiated.
- $T_5$  = Kit Installation commenced.
- $T_6$  = Modification Program completed.

Using this notation, the modification program cost estimate at time of MPD issuance can be denoted by  $MPC(T_3)$  or  $MPC'(T_3)$ . Similarly,  $CP_{21}(.4)$  represents the target

contract price of the first Air Force contract let in the acquisition category.  $CP_{21}(T_6)$  is the final, adjusted price of the same contract. Further use of these time milestones and notation will be deferred until the next chapter.

In summary, a modification program total cost summary can be divided into eight categories. Presently there are no figures available for any of the Government/Air Force costs, save depot kit installation. This is an area worthy of additional research. Neither were any figures found for recurring costs on the modification programs. This research was limited since the only data uncovered at HQ AFLC and the ANAs were contractor incurred costs ( $C_{21}$ ,  $C_{22}$ ,  $C_{23}$ ) and Air Force kit installation costs ( $C'_{12}$ ). This research of the cost growth phenomena is a study of cost variances in these categories.

Cost growth can be examined in at least three ways: the cost-accounting approach, the cost-category approach, and the predictive-functional approach. Each will be dealt with separately. A fourth approach, the subjective, could be included. It is usually more qualitative than quantitative and comprises the compilation of case histories, investigations, and personal experiences. However, the subjective approach is usually an integral part of one of the other approaches.

### The Cost-Accounting Approach

The conventional cost-accounting approach implies analysis of cost variances from established cost standards. There are three major categories by which variances may be analyzed. (43:10-11)

1. Material Category
  - a. Price variance
  - b. Usage variance
2. Labor Category
  - a. Wage rate variance
  - b. Labor efficiency variance
3. Overhead Category
  - a. Volume variance
  - b. Expense variance
  - c. Efficiency variance

By judicious groupings of costs into work packages, functional categories and product components, cost variance analysis can be conducted as to cause and responsibility at a variety of functional, program and organizational levels. (44:24)(45)

For the Air Force to perform such cost variance analysis implies: (1) a requirement for contractors to account costs in this fashion, (2) access to contractor accounting records, and (3) trained personnel assigned to perform the analysis or verify the contractor's data

submissions. It also requires the establishment of acceptable performance standards. A cost accounting approach along these lines is the intent of the Cost/Schedule Control System Criteria (C/SCSC) required on selected acquisitions per DOD Instruction 7000.2, Performance Measurements for Selected Acquisitions. It is however limited to large programs and does not apply to fixed price contracts. (46:1)

### The Cost-Category Approach

The most publicized method of studying cost growth today is the system used by the Department of Defense and described in this thesis subsection, Cost Growth-Evolution and Definition. For selected programs: "programs estimated in the Five Year Defense Program to require (1) a total cumulative financing for Research, Development, Test and Evaluation in excess of \$25 million or (2) cumulative production investments in excess of \$100 million" (24:1), Selected Acquisition Reports (SARs) must be prepared. Program cost, schedule and performance estimates are provided at various baseline time points. This approach is a variation of the cost-accounting approach since the baseline cost estimate serves as a cost performance standard and cost variances must be classified in terms of the nine 'cost growth categories.' Reference Appendix A.

The cost-category approach has helped clarify some of the confusion surrounding cost overrun. It has also aided investigation and research of the phenomena. The approach has recognized that adjustments need be made to the original cost estimate for valid comparisons to be made with the final, actual cost of the program or contract. In theory, it allows for adjustment of the estimate quantities, schedule, performance (engineering changes), price (economic changes) and four other categories or factors. The remaining cost category is called 'cost overrun (underrun).'

An early method of calculating a program or contract cost overrun was:

$$CO = C_f - C_e$$

where

CO = Cost overrun (negative = underrun)

$C_f$  = Final cost, actual

$C_e$  = Estimated cost, earliest available

In its place DOD has substituted:

$$CO = C_f - C_a$$

$$C_a = C'_e + \sum_{i=1}^8 CF_i$$

$$CG = C_f - C'_e$$

$$CO = CF_9$$

where

$C_a$  = Final estimated cost, adjusted

$C_e$  = Estimated cost at an established baseline

$CF_i$  =  $i$ th DOD cost growth category (factor)

$$CG = \text{Cost growth} = \sum_{i=1}^9 CF_i$$

An example of the research contribution arising from the use of these categories is provided by the AFSC Cost Growth Study. (31)

An examination of the 113 completed AFSC contracts revealed a total average cost growth of 49.2% from the initial definitized contract price. Cost variance from the adjusted negotiated contract prices (cost overrun) attributed for 6.4%. Engineering changes accounted for 33.2% of the total cost growth, support changes 24.0%, and quantity changes 22.1%. Recommendations for improvements followed from difficulties in category definition interpretation and data collection.

The DOD cost-category approach appears to have drawbacks. These limitations could not be verified since the performance and schedule data of the SARs is classified and access to them could not be obtained. Cost change categories are established for engineering (performance) and schedule changes. Operational and

technical characteristics and schedule milestones, planned and achieved, must be documented. However, there appears to be no requirement to assess the impact of performance degradation or schedule slippages on costs, unless performance and delivery incentives are included in the contract. The second limitation appears to be the lack of a cause listing or categorization of causes. Variance analyses are to "summarize the underlying causes" (24:8). It could not be verified if causes were supplied or categorized on the SARs. Finally, a negative or zero cost growth could occur, yet there still be an overrun.

Let

$$C_f = C'_e$$

$$CF_2 < 0$$

$$CF_i = 0 \text{ for } i=1,8 \quad i \neq 2$$

$$\text{then } CG = C_f - C'_e = 0.$$

$$C_a = C'_e + \sum_{i=1}^8 CF_i$$

$$\text{implies } C_a < C'_e.$$

$$CO = C_f - C_a$$

$$\text{implies } CO > 0.$$



The above formulation describes the event of reducing the buy quantity to stay at the original cost estimate.

### Adjustments

The previous subsection noted that adjustments are required to the cost estimate. Adjustments prevent an 'apple-orange' comparison of actuals and estimates. Consider this simple example of quantity adjustment. The estimated cost for 100 kits is \$500,000. The final, actual cost is \$500,000. No cost growth occurred, if 100 kits were purchased. However, if only 50 kits were purchased then a cost growth has occurred, and the estimate must be adjusted to determine the extent of the growth.

At least four adjustments may be required to more accurately discuss cost growth and cost overruns.

1. Quantity
2. Price
3. Performance
4. Schedule

Quantity adjustments are described in RAND publications. (47)(48)(49) Adjustments are based on learning curve techniques and the fact a fixed cost exists on any purchase regardless of quantities. Quantity adjustments are typically made based on the major system production quantities, such as aircraft or missiles. In some

procurements Aerospace Ground Equipment (AGE), trainers, simulators, spare parts and technical data constitute a large percentage of the program cost. Changes in their quantities should also be reviewed to determine if the cost estimate should be adjusted accordingly.

Price adjustments are required to the degree the contract price or cost estimate do not allow for fluctuations in the economy. Harmon (50:58-61) shows two methods for adjusting the estimate for price level changes.

As will be demonstrated by the three variable analysis of cost, schedule and performance in the next section, and as briefly noted earlier, an adjustment to the original cost estimate needs to be made if the actual delivery schedule or achieved performance are different from the estimated or required. The cost estimate should usually be deflated if actual delivery schedules are slipped, or design specifications and performance parameters are not met. The techniques necessary for adjusting original cost estimates to compensate for changes in performance and schedule is a potential research area.

#### The Predictive-Functional Approach

The concepts which follow are adaptations of the works of Box (51), Wilde (52), Bartee (53), and Draper and Smith (54). Consider the equation

$$Y = f(\bar{X}, \bar{B}, \bar{R})$$

where

$Y$  = The dependent variable, also called the criterion of effectiveness or response variable.

$f$  = A function or system.

$\bar{X}$  = A vector of independent variables. These are adjustable, controllable factors.

$\bar{B}$  = A vector of boundary variables. Includes factors which are uncontrollable, but measurable, and set controllable factors.

$\bar{R}$  = A vector of random variables. These factors cannot be controlled, adjusted nor measured. They may also be unknown.

This concept can be applied to the procurement process and cost growth.

$Y$  = Program cost outcome

$f$  = Modification procurement process

$\bar{X}$  = Controllable factors, e.g.

$X_1$  = type of contract

$X_2$  = contractor

$X_3$  = AMA manning posture

$\bar{B}$  = Boundary factors, e.g.

$B_1$  = state-of-art technology

$B_2$  = national economy, inflation

$\bar{R}$  = Random factors, e.g.,

$R_1$  = current events

$R_2$  = contractor's evaluator

$R_3$  = acts-of-God

Example: Cost-Schedule-Performance. Probably the most simple and straight-forward example of this concept is the three variable analysis of cost as a function of schedule and performance,  $C = f(S, P)$ . Figure 5 shows a performance contour map. For a given level of performance ( $P_i$ ), cost is a convex function of schedule. Higher levels of performance require longer development time ( $S$ ), cost more, or are some combination thereof. Although this deterministic model oversimplifies the phenomena, it does display the more basic characteristics of the process. Namely, a production or response surface relates these three variables, and trade-offs can

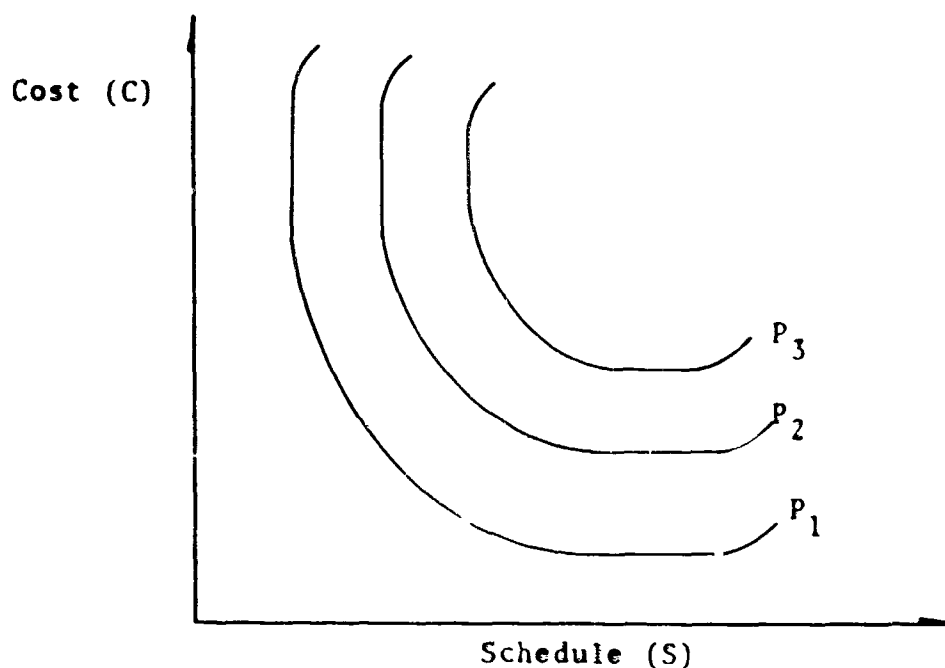


Figure 5. Performance Contour Map.

be made. For a given performance level, costs can be increased by requiring shorter development times. For a given schedule, costs can also increase by requiring higher levels of performance. Peck and Scherer (26:251-257) provide a good introduction to this type of analysis; they also introduce uncertainty (26:299-301). Sapp (55) views it as a response surface and introduces time variant maps and allows for quantity changes.

Literature Examples. The predictive-functional approach has been used in a number of past studies to explain cost growth, predict cost outcomes or make comparisons.

At The RAND Corporation, Summers (29) used a non-linear multiple regression equation and analysis. The functional form of his predictive equation was:

$$F = f(t, A, L, T)$$

where

F = Ratio of actual cost to adjusted estimate

t = Timing of the estimate within the development program expressed as a fraction of program length

A = Degree of technological advance required in the program

L = Length of the development period

T = Calendar year

Perry, et al. (11) also used a nonlinear regression analysis with a predictive equation

$$F = ae^{bM}$$

or in functional form

$$F = f(M)$$

where

a = Regression coefficient

b = Regression coefficient

M = Number of months from the cost estimate to the first operational delivery of the system

Harmon (50) extended the Perry work by reintroducing a Summers variable, A. Harmon's nonlinear multiple regression equation was of the form

$$F = f(A, M)$$

The Rand studies only adjusted the original cost estimates for quantity and price changes.

In other works Belden (12) and Fisher (13) use simple linear regression analysis to examine cost outcomes as functions of the type of contract. The types considered were Fixed Price Incentive (FPI), Cost Plus Incentive Fee (CPIF), and Cost Plus Fixed Fee (CPFF). Belden and Fisher also examined cost outcomes as functions of the contractor's incentive sharing arrangement.

Belden attributed differences in their results in part to changes in the environment over time.

The DCS/S&L Study (17) sought to determine if a correlation existed between the method of procurement (PM) used, type of contract (TC) selected, and program success. In functional form this could be expressed as

$$P = f(PM, TC)$$

$$C = g(PM, TC)$$

where

P = Performance Outcome

C = Cost Outcome

f, g = Function

PM = Procurement Method, e.g.,

PM<sub>1</sub> = two-step advertising

PM<sub>2</sub> = multi-year procurement

PM<sub>3</sub> = total package contracting

TC = Type of Contract, e.g.,

TC<sub>1</sub> = CPFF

TC<sub>2</sub> = CPIF

TC<sub>3</sub> = FPI

In summary, a variety of studies of the procurement process have been conducted in recent years using the predictive-functional approach. Each study attempted to determine whether or not one or more selected variables significantly influenced the cost outcome. Results

were mixed. This condition may have occurred for at least two reasons:

1. Definitions and data bases were different. In most cases data bases were incomplete.

2. Each study made implicit assumptions.

- a. A number of the variables were assumed to be boundary conditions. In truth they were random and contributed to the error term.

- b. One or two independent variables were assumed sufficient to satisfactorily explain the phenomena.

Model Factors. The predictive-functional equation,  $Y = f(\bar{X}, \bar{B}, \bar{R})$ , has been used in various forms to study the procurement process. It is believed that with selective application it can be an extremely useful tool to seek out the causes of cost outcomes. Once a modification program or contract cost outcome is known, statistical analysis can aid in determining which factors, levels, and combinations thereof, significantly affected the outcome. It can also be used for predictive purposes once a data base is established. Table 3 is a selective list of example factors and levels which may impact the cost outcome of a modification program. The factors can be qualitative or quantitative. Some of the qualitative factors can be ranked. Many other factors could and perhaps should be listed. This is another area for future research.



Table 3  
Cost Outcome - Factors and Levels

---

Government Variables

$X_1$  = Air Materiel Area

$X_{11}$  = OCAMA

$X_{12}$  = OOAMA

$X_{13}$  = SAAMA

$X_{14}$  = SMAMA

$X_{15}$  = WRAMA

$X_2$  = Using Command

$X_{21}$  = SAC

$X_{22}$  = TAC

$X_{23}$  = MAC

$X_{24}$  = ADC

$X_{25}$  = ATC

$X_3$  = Program Personnel/Program Cost

$X_{31}$  = Low

$X_{32}$  = Medium

$X_{33}$  = High

$X_4$  = Program Personnel Turnover Rate

$X_{41}$  = Low

$X_{42}$  = Medium

$X_{43}$  = High

Table 3 (continued)

Product Variables

$X_5$  = Technological Advance Sought

$X_6$  = Kit Type

$X_{61}$  = Aircraft

$X_{62}$  = Missile

$X_{63}$  = Communications

$X_{64}$  = Other

Procurement Variables

$X_7$  = Program Priority

$X_{71}$  = Crash

$X_{72}$  = Urgent

$X_{73}$  = Routine

$X_8$  = Funding Support

$X_{81}$  = Timely

$X_{82}$  = Mixed

$X_{83}$  = Delayed

$X_9$  = Procurement Method

$X_{91}$  = Sole Source

$X_{92}$  = Two Step Advertising

$X_{10}$  = Contract Data

$X_{101}$  = Number of Contracts in Program

$X_{102}$  = Number of Letter Contracts Used

Table 3 (continued)

---

$X_{11}$  = Type of Contract

$X_{111}$  = FFP

$X_{112}$  = FPI

$X_{113}$  = CPFF

$X_{114}$  = CPIF

$X_{12}$  = Time Sequencing

$X_{121}$  =  $T_2 - T_1$

$X_{122}$  =  $T_3 - T_2$

$X_{123}$  =  $T_4 - T_3$

$X_{124}$  =  $T_4 - T_1$

$X_{125}$  =  $T_6 - T_1$

Contractor Variables

$X_{13}$  = Proposal Assessment

$X_{131}$  = Optimistic

$X_{132}$  = Realistic

$X_{133}$  = Padded

$X_{14}$  = Past Procurement Performance

$X_{141}$  = High

$X_{142}$  = Average

$X_{143}$  = Low

Table 3 (continued)

---

$X_{15}$  = Percent of Sales - Government Business/Total

$X_{151}$  = 100% - 75%

$X_{152}$  = 75% - 50%

$X_{153}$  = 25% - 50%

$X_{154}$  = 0% - 25%

---

## CHAPTER V

### PROCESS EVALUATION

As is often the case, it is easier to state the fact than to supply a satisfactory explanation. (56:45)

To determine if a modification is cost-effective, the cost must be known. To find the causes of cost outcomes, the outcome must be known. This chapter proposes a methodology for investigating Air Force Logistics Command modification programs to determine their total cost, cost outcome, and causes thereof. The methodology draws upon experiences gained in the conduct of this research and the model concepts of the previous chapter. It can serve as an outline and guide. It requires refinement, by individual specialists, to remove ambiguities, fill lacunae, or broaden the scope as necessary. This chapter presents only the rudiments.

The methodology envisions data collection on all Class V and HQ USAF directed Class IV modification programs as a minimum. If resources permit, the technique could be extended to include all modification programs exceeding a total specified cost, say \$5 million.

The basic responsibility for supplying the data will rest with the Air Materiel Area (AMA) assigned

cognizance over the system or equipment being modified. The bulk of this reporting task will probably fall on the System Support Manager at the AMA. Data analysis and compilation could be the responsibility of any of a number of organizations at Headquarters, Air Force Logistics Command.

#### Data Collection

To investigate modification program cost outcomes, information and data must be collected on a number of subjects in a variety of ways. To determine the causes of cost variances requires even more detailed information. The information should be initially collected as a one time report. It should encompass all active programs and those completed within the last year. If the benefits are worth the cost, collection should continue on a quarterly basis. The types of information necessary appear as subsections and follow.

#### Program History

The program history is a narrative description of the entire modification program. It is a chronological accounting of program events from the establishment of the requirement to the certification of satisfactory installation and operation of the modification. It identifies the source of the requirement and provides the

justification for its need. It details the funding, procurement, engineering, and program management actions taken to translate the operational requirement or deficiency into a viable modification kit, with supporting equipment. It describes the criteria of effectiveness, and measured results, to determine that the operational and technical characteristics specified were achieved, as well as cost-effective. It documents the dates at which program time milestones occurred. The history should strike a balance between depth of coverage and length. It should be a meaningful program synopsis. The average summary should be ten to twenty typewritten pages, double spaced.

#### Tracks and Trade-Offs

Tracks of technical performance, schedule and quantities: required, estimated, approved, achieved, and estimated at program completion, are necessary. Because of the relation of each of these factors to cost, trade-off curves are needed to adjust the cost estimate. The cause of any variance from a previous level or milestone must be identified.

Performance - For each program one or more key operational and/or design (technical) parameters need be selected. The MTBF, properly defined, on the B-52 SAS Program is an example of such a performance parameter.

Each parameter selected must be precisely and clearly defined. Preferably it should be a quantitative, singular value. The performance track should document the value estimated at the first two program time milestones,  $T_1$  and  $T_2$ , approved/required value at the next two milestones,  $T_3$  and  $T_4$ , the present demonstrated value, and its current estimate at program completion. For given schedule times, performance value-cost trade-off curves should be prepared, at least at the time of MPD issuance.

Schedule - A track of delivery schedule, time and quantities, of major components should be prepared. The estimated dates and quantities at the first two milestones, and approved/required figures for the next two milestones should be provided. The track should also provide for the actual schedule achieved, and the current estimate to complete. Depending upon the type of modification and the value of the procured items, tracks may be necessary on one or more of the following items: production kits, AGE, selected spares, trainers, simulators, and technical data. Key events, such as kit qualification test, kit proofing, kit installation, and field-user operational readiness, may also need to be tracked. For given performance levels and fixed quantities, schedule-cost trade-off curves should be prepared, at least at the time of MPD issuance.



Quantity - A track of the numbers of kits procured and installed, and certain major support equipment, is required. Similar to the above tracks, estimated quantities at the first two milestones, required quantities at the next two milestones, and the current estimate of quantities should be provided. For given performance levels and schedules, cost-quantity trade-off relationships should be provided, at least at the time of MPD issuance.

The performance, schedule, and quantity tracks will depict program progress toward specified parameters and events. The trade-off curves will assist in adjusting earlier cost estimates. A priori trade-off curves can remove a certain element of subjectiveness, when adjustments are required at a later date.

#### Cost Summary

An attempt should be made to reflect all costs associated with the modification program. That is, calculate MPC. This cost includes all Government incurred and contractor allowed costs as described in the section Mathematical Models. This cost determination will be helpful in selecting modification program candidates for tracking and pointing out areas of Air Force efficiency. A chart similar to Table 4 should be prepared for each time milestone ( $T_m$ ) as it is reached, as well as one for

the current estimate to complete the program when in-between milestones. This chart would portray the total cost to the Government of the modification program, estimated or actual. For example,  $MPC(T_3)$  would be the estimated total cost at time of MPD issuance, while  $MPC(T_6)$  would be the final, actual total cost. Until cost data is available on all categories, no attempt should be made to adjust these costs for performance, schedule, price, and quantity changes. However, any variances in costs from  $T_m$  to  $T_{m+1}$  should be explained as to cause.

Table 4  
Modification Program Cost (MPC)

Cost Element	Activity		
	Government (i=1)	Contractor (i=2)	Total
Development (j=1)			$\Sigma C_{i1}$
Acquisition (j=2)			$\Sigma C_{i2}$
Initial Logistics (j=3)			$\Sigma C_{i3}$
Recurring (j=4)			$\Sigma C_{i4}$
Total	$\Sigma C_{1j}$	$\Sigma C_{2j}$	$\Sigma \Sigma C_{ij}$

The traditional cost tracking systems for AFLC modification programs should be utilized. The RCS:D-17 Report tracks costs by Budget Program (BP) and Fiscal Year (FY). Associated data shows funding requirements, approvals, and authorizations. Examples of this type data appear in Appendices B and C. The D-17 Report can be useful as a common purpose reference document and to correlate results with older, completed programs. It can also help pinpoint deficiencies in other tracks.

The third cost track proposed is a variation of the cost-category approach. The cost of the modification program to be studied is:

$$MPC'' = \sum_{j=1}^4 C_{2j} + C'_{12}$$

where

$MPC''$  = Extended Modification Program Cost

$\sum_{j=1}^4 C_{2j}$  = Summation of all contractor allowed costs

$C'_{12}$  = Air Force kit installation cost.

This extended cost must be the subject of study since it is the only cost figure for which data is presently available. It 'extends' the abbreviated cost definition ( $MPC'$ ) by including contractor development costs. For each program time milestone an extended modification

program cost estimate,  $MPC''(T_m)$ , would be made.  $MPC''(T_m)$  would be the cost estimate at milestone  $T_m$  to complete the program.  $MPC''(T_0)$  is the actual total extended modification program cost. Comparison of  $MPC''(T_m)$  to  $MPC''(T_k)$ , where  $T_k$  is earlier than  $T_m$ , would yield an unadjusted "cost growth" figure. A more meaningful figure is an adjusted cost,  $\overline{MPC''}(T_m)$ , compared to  $MPC''(T_m)$ . The adjusted cost is arrived at by using the DOD cost change categories to segregate the cost variance.

$$\overline{MPC''}(T_m) = MPC''(T_k) + \sum_{i=1}^8 CF_i$$

Examination of the performance, schedule, and quantity tracks, as well as the trade-off curves, will aid in apportioning the cost variance by categories. The causes for the placement of costs, positive or negative, into any category and for the difference  $MPC''(T_m) - \overline{MPC''}(T_m)$ , must be explained as to cause. Recall that

$$C_{2j} = \sum_{k=1}^{n_j} CP_{jk} . \text{ Thus, for this cost track, cost data}$$

is required by contract for all  $n_j$  contracts in the  $j$ th cost element. As an example, for the C-130 Center Wing Program,  $n_1 = 9$  and  $n_2 = 1$ ;  $CP_{21} = \$83,886,368.$ , Contract F09603-68-C-2530, as of September 4, 1970.

Use of these three cost models will result in AFLC learning: how much a modification program costs, what

was the program cost outcome, and field opinion as to outcome cause.

#### Supplemental Data

The predictive-functional approach can be used to assist in the search for significant factors and outcome causes. Judgment, experience, and cost to collect should dictate which factors and levels are to be examined for significance. Examples of these factors and levels are shown in Table 3, Cost Outcome - Factors and Levels. The supplemental information required is that qualitative or quantitative factor/level data needed for the selected functional form, and not available through the Program History and Cost Summary.

If the predictive-functional approach is used, the response or dependent variable Y should be the modification program cost outcome. Let

$$Y = MPC(T_6)/MPC(T_m)$$

or

$$Y = MPC(T_6) / MPC(T_m)$$

for completed programs; and

$$Y = MPC(\hat{T}_6)/MPC(T_m)$$

or

$$Y = MPC(\hat{T}_6) / MPC(T_m)$$

for active programs, where

$MPC(T_m)$  = Unadjusted estimated modification program cost for  $m = 1,5$

$\overline{MPC}(T_m)$  = Adjusted estimated modification program cost for  $m = 1,5$

$MPC(T_6)$  = Final modification program cost

$MPC(\hat{T}_6)$  = Estimate final modification program cost

A ratio is used for the dependent variable to negate the magnitude effect of large versus small dollar value programs. Current data availability and the willingness to make subjective adjustments for quantities, performance, schedules, and price will dictate the choice of Y. As a minimum the following forms of Y should be examined. Note that for active programs  $T_6 = \hat{T}_6$ .

$$Y = MPC''(T_6)/MPC''(T_m) \quad \text{for } m = 1,5$$

and

$$Y = MPC''(T_6)/MPC''(T_3)$$

Hicks (57) emphasizes 'design' in problem solving. The research planning stage of design proceeds and facilitates the analysis stage. The responsible AFLC group conducting the study should spend the largest portion of their time in designing the study. Deciding beforehand how the submitted data will be analyzed should streamline the data collection process.

### Data Analysis

The analysis and evaluation of the data received must be an active, iterative process. The nature of the data and its analysis will still require a cyclic process to clarify earlier submittals, notwithstanding the initial emphasis on design. Convergence to an optimal format should result.

In conjunction with the data refinement process a cause listing for the cost changes should be developed. It would categorize causes and indicate their relative importance. Such a listing and ranking would provide an order of priority for improvement. The cause listing may be developed from the reasons supplied in the data submittals for cost, performance, schedule, and quantity variances. A second approach to developing a cause listing may be used. It appears in Table 5 and is based on the concepts of the Procurement Process Model. Table 5 is based on four premises.

1. All causes originate within a system.
2. Causes are controllable or non-controllable.
3. The control device is responsible for controllable causes.
4. Controllable causes can be attributed to the decision function and its component outputs:
  - a. Intelligence Output
  - b. Evaluator Design
  - c. Process Design
  - d. Process Control

**Table 5**  
**Program Cost-Change-Cause Table**

<u>Controllable Causes</u>					
	<u>Decision Function Outputs</u>				
System	Intelligence Output	Evaluator Design	Process Design	Process Control	Total
#1					
#2					
#3					
.					
.					
.					
#N					
Total					

### Non-Controllable Causes

<u>Description</u>	<u>System</u>	<u>Value</u>
--------------------	---------------	--------------



An example of how program data would be analyzed and input to this table may be found in the next section.

Once data becomes available on which programs and contracts, are or are not, experiencing cost growth and cost overruns, then a variety of statistical analysis techniques may be applied. The seriousness of the problem may be assessed and factors and causes isolated. It can be tabbed a 'which hunt'; a search for which of the factors and causes significantly affect the cost outcome.

#### Evaluation of Case History Programs

Figures 6 and 7 recap the C-130 Center Wing Replacement and B-52 Stability Augmentation System Installation Programs from another viewpoint. Stacked graphs are used. By plotting available information against a common abscissa, the time related activities of these modification programs can be better visualized. Given additional details, other tracks could be made and relationships demonstrated. Notes accompany each figure.

The remainder of this section examines the cost growth aspects of these programs using concepts previously discussed. The presentation is heavily subjective. Independent judgment had to be used, as available data and techniques were inadequate to do otherwise.

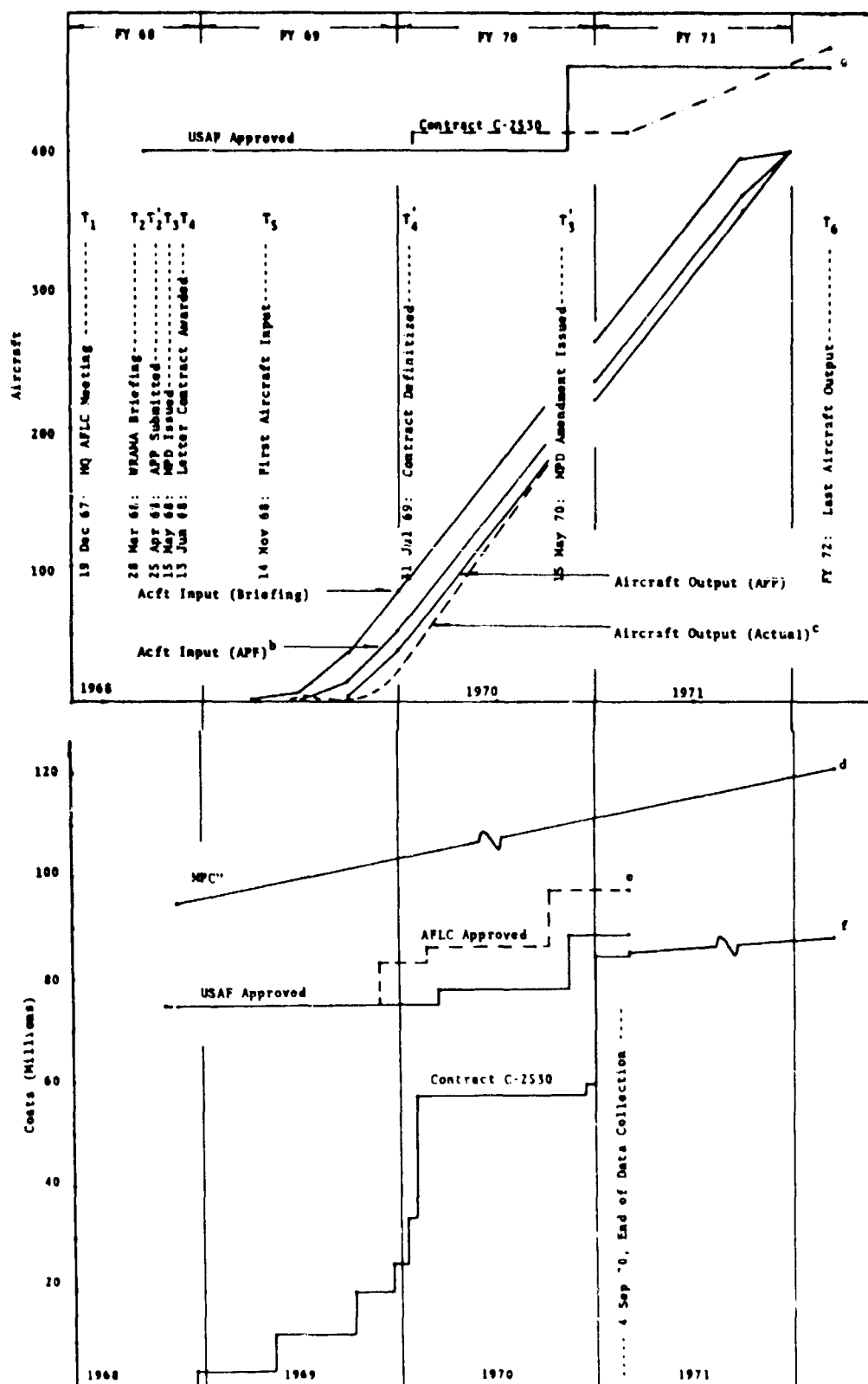


Figure 6. Stacked Time Graph: C-130 Program.

### Figure 6 Notes

<sup>a</sup>The current approved quantity of USAF C-130 aircraft to be modified is 460. The MPD Amendment of May 15, 1970 allowed for the addition of 60 HC-130 H and P models. Contract F09603-68-C-2530, when definitized in July 1969, added 12 USCG aircraft to the originally planned 400 USAF aircraft. The program forecast is for 516 aircraft: 460 USAF, 16 USCG, and 40 USN. As of September 1970, the contract had not been changed.

<sup>b</sup>The two aircraft input schedules depicted are those presented to HQ USAF in the WRAMA Briefing and the later Advanced Procurement Plan (APP). The actual aircraft input achieved, and has maintained, the APP/MPD schedule since June 13, 1969.

<sup>c</sup>Additional data on actual aircraft output schedules is shown in Figure B2. Output achieved the original APP/MPD schedule on June 30, 1970.

<sup>d</sup>Per Table 6, data on the Extended Modification Program Cost, MPC", was available only for time milestones T<sub>3</sub> and T<sub>6</sub>. This figure differs from the USAF Approved<sup>3</sup> (MPD) track by the amount of development costs.

<sup>e</sup>The AFLC Approved cost track represents the dollar amounts approved on associated AFLC Forms 48. It differs from the USAF Approved cost track since the AFLC track includes the price of performing the outer wing rainbow fitting modification.

<sup>f</sup>The cost track for Contract C-2530 is obligated dollars. The total obligated by the Air Force as of September 1970 was \$83.9 million. The estimated cost to complete is \$85.9 million. The latter figure is comprised of the Total Target Price and the cost of Over and Above Work, GFM, and spares. See Table 6B.

<sup>g</sup>Fiscal year lines are included to highlight the number of monetary actions taken in the first and fourth fiscal quarters of each year.

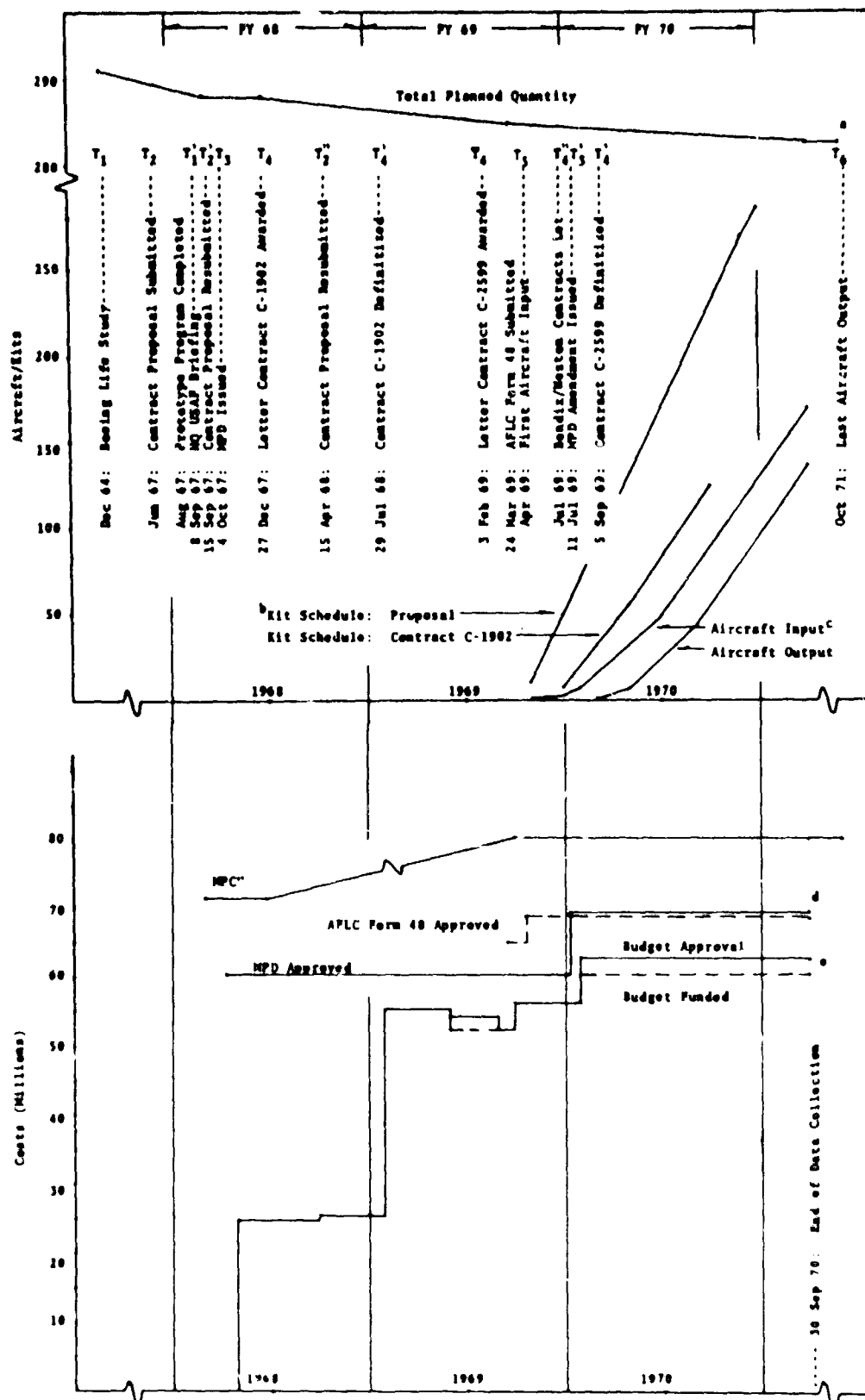


Figure 7. Stacked Time Graph: B-52 Program.

## Figure 7 Notes

<sup>a</sup>A scale change was made to more accurately reflect changes in the total planned quantity. The number of aircraft to be modified decreased due to attrition.

<sup>b</sup>The kit schedules are planned quantity tracks. The original Boeing proposals were for 288 kits, however Contract F34601-68-C-1902 was issued to Boeing for the purchase of only 125 kits. The components for the remaining kits were purchased separately under seven contracts.

<sup>c</sup>Aircraft input and output tracks are actuals. They reflect when B-52 aircraft were input and output from the Air Materiel Areas at San Antonio and Oklahoma City. See Table 7C.

<sup>d</sup>The MPC", AFLC Form 48, and MPD Approved cost tracks are defined in the same manner as used in Figure 6. The MPD Approved means the same as USAF Approved. An AFLC Form 48 was not submitted on this program until March 1969. The amendment to the MPD on July 11 allowed \$0.4 million more for BP1100 in FY 69 than did the revised AFLC Form 48 of April 28, 1969. See Tables 4C and 5C.

<sup>e</sup>Budget approval and funded data came from the LOG D-20 Report. The track reflects actual dollars approved and funded for the program on an incremental basis.

### The C-130 Program

If unadjusted cost figures are used then two interpretations of the cost outcome on the C-130 Program are possible, depending upon which time base is used. Reference Table 6. One, either a cost decrease of \$5.3 million (\$125.0-\$119.7) occurred; or two, a cost growth of 26.9% or \$25.4 million (\$119.7-\$94.3) occurred. If the  $T_3$  cost estimate is adjusted for aircraft quantity only using an 85% learning curve, then a cost growth of 17.8% or \$18.1 million (\$119.7-\$101.6) occurred. In these calculations only the production cost is adjusted. The cost factor  $F = MPC''(\bar{T}_6)/MPC''(T_3)$  shows an unadjusted factor of 1.27; adjusted  $F' = 1.18$ . No adjustment was made for price since it was reflected in the contract price.

The cost growth figure of \$25.4 million can be segregated according to the nine cost change categories. As discussed earlier categorization does not provide causes, it merely serves to isolate dollars and begin the search for causes. Changes in the development program cost element ( $C_{21}$ ) account for \$2.8 million. This growth stemmed from changes in five contracts ( $n_1 = 5$ ). The changes by cost category for the production program cost element ( $C_{22}$ ) can be:

Table 6  
USAF C-130 Center Wing Program

Costs <sup>2</sup>	T <sub>1</sub> 12/67	T <sub>2</sub> 3/68	T <sub>3</sub> 5/68	T <sub>4</sub> 6/68	T <sub>5</sub> 11/68	T <sub>6</sub> <sup>1</sup> 9/70
Development	--- <sup>3</sup>	---	19.6 <sup>4</sup>	---	---	22.4
Production	---	75.3	74.7	74.7	74.7	97.3
Total	125.0	---	94.3	---	---	119.7
Quantity	---	400	400	400	400	460

Note 1. T<sub>6</sub> = Current estimate to complete.

Note 2. Cost = MPC" in millions.

Note 3. --- = Not available.

Note 4. Estimates of total development cost could not be found. This figure is a composite guesstimate of costs as incurred and planned through 12/68.

$CF_1$  = Engineering Change = +\$9.3 million

$CF_2$  = Quantity Change = + 7.3

$CF_3$  = Support Change = + 0.5

$CF_7$  = Estimating Change = + 5.5

---

Total = +\$22.6 million

The proportioning rationale is as follows:  $CF_1$  = \$9.3

for incorporation of outer wing rainbow fittings;

$CF_2$  = \$7.3 for addition of 60 aircraft;  $CF_3$  = \$0.5 for

additional spares; and  $CF_7$  = \$5.5 for the GFM (\$2.2)

and residue (\$3.3). All other categories are zero.

The causes for the \$25.4 million cost growth are many.

Some are stated in Appendix B, particularly the Summary, others in the Conclusion.

The following scenario analysis is offered to demonstrate how Table 5 could be used in the search for and categorization of causes. Consider  $CF_1$  = \$9.3 million. HQ AFLC approval was granted to permit incorporation of outer wing rainbow fittings on 400 aircraft in May 1969 (\$8.05M) and on an additional 60 aircraft in April 1970 (\$1.25M). WRAMA and Lockheed were aware of the need for this effort as early as April 1968. The probable causes for this increase were: the desire for additional work on the part of the contractor after program initiation; and the desire of the Government to reduce total aircraft downtime, switch funding sources, and minimize



initial program total cost. The causes would be controllable and attributable to System 3, Buying Office, and System 4, Contractor. If a subjective judgment of 50/50 responsibility were made, then 18.3% of the cost growth would be placed under the abscissa coordinate Process Control for both Systems. Recall that the \$9.3 million was 36.6% of the total cost growth. This analysis is conjecture and offered only to exemplify the use of Table 5. As noted in Appendix B, the causes for this increase could not be validated nor corroborated.

#### The B-52 Program

For the B-52 SAS Program, summary cost and quantity data is presented in Table 7. If unadjusted cost figures are used, a cost growth of 13.3% or \$9.6 million (\$81.7-\$72.1) occurred. Adjusting the production cost for the decrease in quantity, using an 85% learning curve, yields a cost growth of 14.1% or \$10.1 million (\$81.7-\$71.6). The cost factors are:  $F = 1.13$  and  $F' = 1.14$ .

In a similar fashion to the C-130 review, the cost growth of \$9.6 million can be segregated by change categories.

Table 7  
B-52 Stability Augmentation System Program

Costs <sup>2</sup>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub> <sup>1</sup>
	12/64	9/67	10/67	12/67	4/69	6/70
Development	--- <sup>3</sup>	12.0	12.0	12.0	12.0	12.0
Production	32.2	60.1	60.1	60.1	69.1	69.7
Total	---	72.1	72.1	72.1	81.1	81.7
Quantity <sup>4</sup>	291	288	288	288	285	283

Note 1. T<sub>6</sub> = Current estimate to complete.

Note 2. Cost = MPC" in millions.

Note 3. --- = Not available.

Note 4. One unit prototyped, installed, but not included.

$CF_1$  = Engineering Change = -\$ 6.3 million

$CF_2$  = Quantity Change = - 0.5

$CF_3$  = Support Change = + 3.9

$CF_7$  = Estimating Change = + 12.5

Total = +\$ 9.6 million

The proportioning rationale is as follows:  $CF_1$  = -\$6.3 for reorganizing black boxes, i.e., adopting Configuration #1;  $CF_2$  = -\$0.5 for deleting five units;  $CF_3$  = \$3.9 for changes in provisioned items; and  $CF_7$  = \$12.5 for residue, which cannot be quantified into any other category at this time. If viewed in this fashion, the B-52 SAS Program could be said to have incurred a 25.1% cost growth. The final estimated cost  $\bar{T}_6$  = \$81.7 million and the  $T_3$  cost estimate when adjusted for performance and quantity changes is \$65.3 million (\$72.1-\$6.8), thus the cost grew by \$16.4 million. The causes are many and interrelated. Some are stated in Appendix C, particularly in the Summary; others in the Conclusion.

The difficulty of apportioning costs by these categories becomes obvious when one attempts it. An a priori set of cost-schedule-quantity-performance trade-off curves would help; so too would more detailed cost tracks. As shown above no figure could be assessed to overrun or underrun ( $CF_9$ ). Generally speaking this cannot be done until the contract(s) are completed.

Undoubtably many persons will take issue with the above apportionments and numbers. As noted earlier, it is a subjective judgment on the part of the researcher. One or more different sets of numbers may be offered in lieu of the above. The figures may stir controversy. Such discussion should merely reinforce the need for a uniform set of definitions and data. For Air Force Logistics Command to recognize the problem and work toward its solution now, will be infinitely better than later.

## CHAPTER VI

## CLOSURE

This chapter concludes the dissertation. It contains three sections. The Summary presents a brief synopsis of this research. The Conclusions are the judgments, decisions and opinions formed after investigation and thought. Recommendations to improve the procurement process, particularly in AFLC, complete this chapter.

Summary

The process by which the Department of Defense acquires new weapon systems and modifies existing systems is extremely complex. Because of the large dollar amounts involved and the democratic form of government in the United States, the process is subject to intense public scrutiny. When these factors interact with the American desire for peak efficiency, any apparent wasteful practice by the Department of Defense unleashes a torrent of criticisms and suggestions for improvement. Because the process is complex, it defies simple remedies. Because the process is dynamic, it rejects static solutions. When simple, quick remedies and static solutions fail, the scrutiny, criticism and suggestions intensify

and multiply. Improvement becomes more crucial and difficult. Such is the case with the current problem of 'cost overruns.'

The purpose of this research is to provide a better understanding of the Department of Defense procurement system. It searches for the causes of program cost outcomes. A systems approach is used to address the problem. The end goal is improvement of the procurement process. The research concentrates on the procurement of major aircraft modifications by the Air Force Logistics Command (AFLC).

Understanding of a process leads to control. Intelligent control can result in improvement. In order to improve the process for procurement of modifications, and to determine the causes of cost overruns, understanding is necessary. An examination was made of this process and the terms cost overruns, cost growth, and numerous others. The evolution of the term cost overrun into cost growth is traced. The distinction between cost growth change categories and causes is made.

A literature search oriented toward cost growth and its causes, especially on AFLC modification programs, was conducted. The search indicated that the Air Force Systems Command (AFSC) had borne the brunt of public and congressional criticism on program and contract cost growths. AFSC, responsible for the development and

acquisition of new weapon systems for the Air Force, had also been the subject of numerous studies and Congressional inquiries. Minimal data was available on modification program cost growth. Less information was available on the causes for this phenomenon in AFLC; a data base was lacking. Because of the decentralized procurement policy of the Air Force and AFLC, detailed program information on costs, schedules and performance is available only at the Air Materiel Area (AMA) assigned Air Force responsibility for managing the procurement and incorporation of the modification.

Two large aircraft modification programs were selected for study. Case histories of each program were compiled by record reviews and personnel interviews at HQ AFLC and the AMAs. The programs studied were:

1. The C-130 Center Wing Class IV Modification directed by Warner-Robins Air Materiel Area and performed by the Lockheed-Georgia Company.

2. The B-52 Stability Augmentation System Class IV Modification directed by the Oklahoma City Air Materiel Area, having kits manufactured by the Boeing-Wichita Company and other vendors, and installed at Oklahoma City and San Antonio Air Materiel Areas.

The purpose of the compilation of these histories was to gain insight into the process, determine data availability, and see if causes of the cost outcome could be

determined. The investigation can be viewed as a pilot study of cost outcomes on large modification programs. It can serve as a departure point for construction of a designed experiment; one which can objectively determine cost outcome causes.

Models of the procurement process and program cost outcomes were developed in order to relate the many causes uncovered explaining the cost growth phenomenon. Systems diagrams and mathematical models were developed. Based on this modelling and the program reviews, a methodology for investigating Air Force Logistics Command modification programs is proposed. The methodology strives to determine the cost outcomes, and if cost growth is occurring, its causes.

### Conclusions

The compilation and study of two case histories indicated that sufficient data is not readily available in AFLC to determine program cost outcomes or their causes. Until such data can be made available for analysis, subjective judgments must play a major role in rendering an after-the-fact, program-by-program answer to the question, "What causes cost overruns on large modification programs?"

The total program cost is an additive figure of Government and contractor incurred costs. To determine a modification program cost, all these costs must be recognized and accounted for. At present, the AFLC "cost of modification" omits some of these factors. For example,



contractor incurred development costs are not included. This fact accounts for part of the difference between the USAF Approved and Extended Modification Program Cost (MPC") on the C-130 Program. (Figure 6, p. 92)

The cost, schedule, and performance parameters of any modification program are related. The program cost can be described as a function of schedule and performance. To determine the causes of cost overruns requires knowledge of comparable beginning and end points regarding cost, schedule, quantity, and performance parameters. The B-52 case history indicated such data was not readily available. Schedules, quantities, and configuration of the delivered modification kits were different from that originally approved (p. 39). Lacking a priori trade-off curves on schedule-cost-performance, or documented justification for changes, subjective judgments must be rendered to adjust the data in order to determine the final program cost outcome. Conservative adjustments show a cost growth of 18% on the C-130 Program and 25% on the B-52 Program.

Prior to August 1970, no official Department of Defense definition existed for the term "cost overrun." The pre-1970 interpretation of the term varied according to the user's viewpoint, therefore past studies and information on cost overruns and their causes are often not comparable. For example, two HQ USAF studies conducted in 1969 used entirely different definitions of "contract

cost overrun" (pp. 15-16). In 1969 the term "cost growth" was introduced. In August 1970 the term "contract cost overrun" became a subcategory of cost growth. This situation created a communications barrier which still exists. The current, standardized DOD definitions need to permeate all levels of AFLC procurement. Elimination of this communications problem will focus needed emphasis on the cost growth phenomena and aid future research.

Another conclusion of this research is that the systems approach is a useful technique for describing and understanding the Department of Defense procurement process. By using this approach a model of the procurement process is developed (pp. 43-56).

The value of the application of the systems approach to this problem is its replacement of a parochial viewpoint of the procurement process with a catholic viewpoint. By using the systems approach and the procurement process model one becomes aware of the large number of systems involved in the process and the multiplicity of relationships which exist among these systems. The systems approach and model refute the notion that a single cause is at the root of the total cost overrun problem. Also, it highlights the fact that changes or improvements made to one system do affect other systems. Most previous studies on program outcomes concentrated on a single aspect of the procurement process. The procurement process model aids in relating these studies, one to the

other, and puts them in perspective to the total process (p. 55).

By use of the model, a scheme for classifying causes of program cost outcomes is developed (pp. 90-91). Causes are classified as controllable or non-controllable. Controllable causes are assigned to one or more of the systems in the procurement process model. Within the system the cause is attributed to one of four decision function outputs: intelligence output, evaluator design, process design, or process control. A scenario analysis with C-130 program data exemplifies its use (pp. 98-99). Additional verification and extension of the model is dependent upon collection of the noted data.

From an examination of the case histories it was concluded that these large modification programs exhibit the basic characteristics of major weapon system acquisition programs (pp. 40-41). It is shown that the procurement process model is applicable to such modification programs as well as acquisition programs. It was further concluded that because of the similarity in the procurement process for large modification programs and major weapon system acquisition, the reasons uncovered to date for explaining program variances in the latter may be applied to the former and vice versa. For example, acquisition programs have long suffered from initial contractor and/or Government optimism. The case studies reveal that optimistic proposal cost and schedule figures were

used to sell the modification programs to HQ USAF. The initial optimism was tempered when definitized contracts were awarded. HQ USAF acceptance of optimistic original estimates resulted in the placement of tight financial, schedule, and performance constraints and pressures on program personnel. The result was that the Government decision-making process in these programs was heavily weighted toward cost increase avoidance. Schedule and performance followed in that order of importance in the decision-making process. There was no indication that this condition was limited to these two modification programs.

#### Recommendations

An objective of this research was to develop recommendations which would reduce or minimize unwarranted program cost growths. The research indicates that two avenues are available which can lead to improvement of the AFLC Modernization Program and achieve the above objective. One avenue is long-range in scope; the second can provide short term improvement.

As indicated by the foregoing discussion, adequate information can not be readily obtained from available sources to properly determine program outcomes nor their causes. The long-range solution is to conduct a thorough study of Class V and HQ USAF directed Class IV modification programs. Therefore, it is recommended that the Air Force Logistics Command form an Ad Hoc Cost Research

Group to investigate cost outcomes on large modification programs. The Cost Research Group would first, collect and analyze the data necessary to pinpoint significant factors and causes of cost growth; and second, make recommendations to the Commander, Air Force Logistics Command, that would reduce or minimize unwarranted cost growths.

The Ad Hoc Cost Research Group should:

1. Be chartered by the Commander, AFLC.
2. Consist of AFLC personnel. In addition to a team leader, specialists would be required at least in the areas of financial management, contracts/pricing, provisioning, program management, and engineering. All should be intimately familiar with AFLC and the Modernization Program. The Research Group can be supplemented by consultants. Air Force personnel knowledgeable in statistics, economics, data processing, law, or other required fields could serve on an 'as-needed' basis.
3. Study all active Class V and HQ USAF directed Class IV modifications as well as those completed within the last year.
4. Use the concepts for data collection and analysis presented in Chapter V, Process Evaluation, of this thesis (pp. 79-91).
5. In conjunction with the DCS/Comptroller, develop a Selected Modification Report (SEMORE). The Process Evaluation concepts (pp. 79-91) and Enclosure 1 to DODI 7000.3 (24) should be used to formulate the SEMORE. The SEMORE would provide management visibility on modification

programs similar to the Selected Acquisition Report (SAR) on development and acquisition programs.

If the following recommendations are implemented by HQ AFLC, immediate improvement in the management of large modification programs may be achieved.

1. Require that the need for any new modification be more adequately justified and documented before program initiation. The documentation should reflect that the increased effectiveness of the modification justifies the total program cost. Reaffirm the role of the Configuration Control Boards in assuring compliance with this task. Adhere to established procedures for initiation of a modification program. An AFLC Form 48 was not submitted on either program initially; program approval was given on the basis of a HQ USAF briefing.

2. Require that the documentation for justifying a cost increase be more detailed. The cause for the increase should be provided as well as the action taken to prevent recurrence. It should also be required that the root causes for schedule, quantity, and performance changes be documented since the modification cost is a function of their values (p. 28).

3. Require that one or more performance parameter be specified and tracked for each modification similar to present cost and schedule tracks.

This research uncovered areas worthy of additional study. The procurement process model should be extended

to include more systems (pp. 53-54). Within AFLC the following topics should be researched:

1. A compilation of costs: types and amounts, attributable to the Government and Air Force in modifying a weapon system (pp. 83-84).

2. Development of performance-cost and schedule-cost analysis techniques and nomographs for adjusting original cost estimates (pp. 81-83).

3. The impact on the decision-making process and program cost growth of the "average time" to process the AFLC Form 48 through the Configuration Control Board. Both programs experienced delays in processing these forms through HQ AFLC for approval of program changes; meanwhile daily program decisions had to be made at the AMA.

4. Additional case histories should be compiled along the lines of Appendices B and C; not only on aircraft, but also on missile, electronic and ground equipment modifications.

## BIBLIOGRAPHY



## BIBLIOGRAPHY

1. U.S. Department of Defense, Armed Services Procurement Regulation, 1969 ed., USGPO, Washington, 1969.
2. U.S. Congress, House of Representatives, Subcommittee of the Committee on Government Operations, Government Procurement and Contracting (Part 1), Hearings, 91:1, USGPO, Washington, March 18, 19, 20 and 24, 1969, pp. 254-302.
3. Government Procurement and Contracting (Part 4), Hearings, 91:1, USGPO, Washington, April 23, 29 and 30, 1969, pp. 1150-1162.
4. U.S. Air Force, Systems and Equipment Modernization/Maintenance Programs, RCS: AF-D17, AFR 27-8, May 6, 1966.
5. Modification Programs, AFR 66-43, October 23, 1968.
6. Retrofit Configuration Changes, AFR 57-4, June 23, 1970.
7. U.S. Department of Defense, "Statement of Secretary of Defense Melvin R. Laird Before a Joint Session of the Senate Armed Services Committee and the Senate Subcommittee on DOD Appropriations on the Fiscal Year 1971 Defense Program and Budget," Department of Defense, Washington, February 20, 1970.
8. U.S. Comptroller General, General Accounting Office, Status of the Acquisition of Selected Major Weapon Systems, Comptroller General of the United States, Washington, February 6, 1970.
9. Drake, Hudson B., "Major DOD Procurements at War with Reality," Harvard Business Review, January-February 1970, pp. 119-140.
10. "Contract Procedures Cause Cost Overruns," Industrial Research, August 1969, p. 35.

11. Perry, R. L., DeSalvo, D., Hall, G. R., Harmon, A. J., and Levenson, G. S., System Acquisition Experience, RM-6072-PR, The RAND Corporation, Santa Monica, California, November 1969.
12. Belden, David Leigh, Defense Procurement Outcomes in the Incentive Contract Environment, TR-69-2, Industrial Engineering Department, Stanford University, California, May 1969.
13. Fisher, Irving N., A Reappraisal of Incentive Contracting Experience, RM-5700-PR, The RAND Corporation, Santa Monica, California, July 1968.
14. Lorette, Richard J., The Relationship Between Pressures on the System Program Director and the Growth of Weapon System Cost Estimates, Ph.D. Dissertation, Harvard University, June 1967. Revised April 1969. Abridged version, "Cost Estimate Growth Pressures Influencing the Air Force SPO Director in His Decision-Making Role," National Contract Management Journal, Vol. 4, No. 1 (Spring 1970), pp. 1-29.
15. U.S. Air Force, Comptroller, An Analysis of Weapon Systems Contract Cost Growth, MA-69-10, July 3, 1969, (FOUO). ✓
16. U.S. Air Force DCS/Systems and Logistics, Directorate of Procurement Policy, Study of Cost Overruns on Class V Modification Programs, undated, circa April 1969 (FOUO). ✓
17. \_\_\_\_\_, Study of Methods of Contracting for Weapons Systems and Major Modification Programs, undated, circa July 1969.
18. Merrell, General Jack G., "Contract Program Cost Overruns/Growth," MCG Letter, Wright-Patterson AFB, Ohio, June 19, 1969.
19. U.S. Air Force, Air Force Logistics Command, Maintenance Engineering, Modification Cost Estimates, March 26, 1969.
20. U.S. Congress, Joint Economic Committee, Subcommittee on Economy in Government, The Economics of Military Procurement, Hearings, 91:1, USGPO, Washington, November 11-14, 1968 and January 16, 1969.
21. Mehl, Richard A., "Analysis of the Term Cost Overrun and Its Evolution into Cost Growth," Unpublished paper, College of Business Administration, George Washington University, April 16, 1970.

22. U.S. Department of Defense, Selected Acquisition Reports (SAR), DODI 7000.3, December 19, 1969.
23. Packard, David, "Cost Growth Definitions," OSD Memorandum, Washington, August 5, 1970.
24. U.S. Department of Defense, Selected Acquisition Reports (SAR), DODI 7000.3, June 12, 1970.
25. Webster's Third New International Dictionary, G & C Merriam Company, Springfield, Massachusetts, 1961.
26. Peck, M. J. and Scherer, F. M., The Weapons Acquisition Process: An Economic Analysis, Harvard University Press, Cambridge, Massachusetts, 1962.
27. Novick, David, Are Cost Overruns a Military-Industry Complex Specialty, P-4311, The RAND Corporation, Santa Monica, California, March 1970.
28. Marshall, A. W. and Meckling, W. H., Predictability of the Costs, Time and Success of Development, The RAND Corporation, P-1821, December 11, 1959. Also in The Rate and Direction of Inventive Activity, Princeton University Press, Princeton, 1962, pp. 461-475.
29. Summers, R., Cost Estimates as Predictors of Actual Weapons Costs: A Study of Major Hardware Articles, RM-3061-PR, (Abridged), The RAND Corporation, Santa Monica, California, March 1965, (Original Classified, April 1962). Also in Marschak, Glennan, and Summers, Strategy for R&D: Studies in the Microeconomics of Development, Springer-Verlag, New York, 1967, pp. 140-189.
30. Marschak, T. A., The Role of Project Histories in the Study of R&D, P-2850, The RAND Corporation, Santa Monica, California, January 1964. Also in Marschak, Glennan and Summers, Strategy for R&D: Studies in the Microeconomics of Development, Springer-Verlag, New York, 1967, pp. 49-139.
31. U.S. Air Force, Air Force Systems Command, Directorate of Procurement Support, AFSC Cost Growth Study, Andrews AFB, Maryland, March 2, 1970.
32. Deavers, K. L. and McCall, J. J., An Analysis of Procurement and Product-Improvement Decisions, RM-3859-PR, The RAND Corporation, Santa Monica, California, November 1964.
33. Deavers, K. L., Product Improvement Candidate Selection and Management Information, RM-4324-PR, The RAND Corporation, Santa Monica, California, November 1964.

34. Sweetland, A., Assessing the Impact of Weapon System Modifications by Field Study: A Feasibility Demonstration, RM-4523-PR, The RAND Corporation, Santa Monica, California, November 1964.
35. Aerospace Industries Association, The Essential Steps and Related Uncertainties in DOD Weapon System Development, Aerospace Industries Association, Washington, October 1968.
36. "National Security Industrial Association Defense Acquisition Study," National Contract Management Association Newsletter, October 1970, pp. 5-6.
37. Reed, Ruddell, Jr., "The Nature of Systems Analysis and Design," Unpublished paper, Purdue University, Lafayette, Indiana, August 1969.
38. Nelson, Rosser T., "A Decision-Making Model for Applications of Queueing Theory," Working Paper No. 147, Western Management Science Institute, University of California, Los Angeles, February 1969.
39. ., "A Research Methodology for Studying Complex Service Systems," AIIE Transactions, Vol. 1, No. 2, June 1969, pp. 97-105.
40. Forrester, Jay W., Industrial Dynamics, MIT Press, Cambridge, Massachusetts, 1961.
41. Proxmire, William, Report from Wasteland-America's Military-Industrial Complex, Praeger Publishers, New York, 1970.
42. U.S. Department of Defense, Life Cycle Costing Procurement Guide (Interim), LCC-I, July 1970.
43. Davis, Roger L., "A Definition of Cost Overruns," Unpublished paper, School of Systems and Logistics, Wright-Patterson AFB, Ohio, May 1969.
44. Teubner, Harold D., "Cost Management-Set Goals, Measure Progress, Correct Problems," Defense Industry Bulletin, March 1970, pp. 21-25.
45. "The Analysis of Manufacturing Cost Variances," Research Report 22, National Association of Accountants, New York, 1952.
46. U.S. Department of Defense, Performance Measurements for Selected Acquisitions, DODI 7000.2, October 15, 1969.

47. Asher, Harold, Cost-Quantity Relationships in the Airframe Industry, R-291, The RAND Corporation, Santa Monica, California, July 1956.
48. Noah, J. W. and Smith, R. W., Cost-Quantity Calculator, RM-2786-PR, The RAND Corporation, Santa Monica, California, January 1962.
49. Henrichsen, Susan, "Example of Quantity Adjustment in Calculating Cost Factors," The RAND Corporation, Santa Monica, California, November 1970.
50. Harmon, Alvin J., A Methodology for Cost Factor Comparison and Prediction, RM-6269-ARPA, The RAND Corporation, Santa Monica, California, August 1970.
51. Box, G. E. P., "The Exploration and Exploitation of Response Surfaces," Biometrics, 10, 1954.
52. Wilde, Douglass J., Optimum Seeking Methods, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1964.
53. Bartee, Edwin M., Engineering Experimental Design Fundamentals, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1968.
54. Draper, N. R. and Smith, H. Applied Regression Analysis, John Wiley & Sons, Inc., New York, 1966.
55. Sapp, Richard S., "Response Surfaces and the Cost Growth Phenomena," Paper, 26th Military Operations Research Society Symposium, Naval Postgraduate School, Monterey, California, November 19, 1970.
56. Kleijn, H., Mushroom and Other Fungi, Doubleday, Garden City, New York, 1962.
57. Hicks, Charles R., Fundamental Concepts in the Design of Experiments, Holt, Rinehart and Winston, Inc., New York, 1964.

APPENDIX A  
GLOSSARY OF TERMS

APPENDIX A  
GLOSSARY OF TERMS

Appropriation - An authorization by an Act of Congress to make payments out of the Treasury for specified purposes within a prescribed amount. (AFLCM 400-6)

Budget Authorization (BA) - The authority, when accompanied by a cash allotment, to incur a commitment and obligation of the Government to pay funds. Reference Procurement Authorization.

Budget Program (BP) Codes - A subdivision established under an appropriation to identify a significant segment of Air Force operations by system or program category.

BP-11 - A Budget Program under Appropriation 3010 for aircraft modifications; covers the cost of the modification kit, installation engineering, special tools and technical data.

BP-15 - A Budget Program under Appropriation 3010 for replenishment spares required to support maintenance of aircraft and related equipment.

BP-16 - A Budget Program under Appropriation 3010 for initial spares and spare parts in support of in-production aircraft, modification of in-service aircraft, direct AGE and training devices.

6E - A budget code under Appropriation 4922, Air Force Industrial Fund; covers cost of depot maintenance. Previously referred to as DMIF (Depot Maintenance Industrial Fund).

6H - A budget code under Appropriation 4921, Air Force Stock Fund; covers the cost of expense type items. Reference BP-15.

Change Order - A written order signed by the contracting officer, directing the contractor to make changes which the Changes clause of the contract authorizes the contracting officer to order without the consent of the contractor. (ASPR)

Commitment - An amount administratively reserved for future obligation against available funds, based upon firm requisitions, purchase requests, directives requiring commencement of actual procurement actions, or other written evidence, on acceptable forms of intention to incur obligations.

Configuration Item (CI) - An aggregation of hardware or software, or any of its discrete portions, that satisfies an end use function and is designated by the Government for configuration management. CIs may vary widely in complexity, size, and type--from an aircraft or electronic system to a test meter or round of ammunition.

Contract - All types of agreements and orders for the procurement of supplies or services. It includes awards and notices of award; contracts of a fixed-price, cost, cost-plus-a-fixed-fee, or incentive type; contracts providing for the issuance of job orders, or task letter thereunder; letter contracts, and purchase orders. It also includes supplemental agreements with respect to any of the foregoing.

Contract Modification - Any written alteration in the specification, delivery point, rate of delivery, contract period, price, quantity, or other contract provisions of an existing contract, whether accomplished by unilateral action in accordance with a contract provision, or by mutual action of the parties to the contract. It includes (i) bilateral actions such as supplemental agreements, and (ii) unilateral actions such as change orders, administrative changes, notices of termination, and notices of the exercise of a contract option. (ASPR)

Contract Price - The sum total of a contract cost and profit or fee, estimated or actual.

Cost Growth Categories (OSD Memorandum, 5 Aug 70)

Engineering Change - An alteration in the physical, or functional characteristics of a system or item delivered, to be delivered, or under development, after establishment of such characteristics.

Quantity Change - A change in quantity to be procured, the cost of which is computed using the original cost-quantity estimating relationships, thereby excluding that portion of the current price attributable to changes in any other category.



Support Change - A change in support item requirements (e.g., spare parts, training, ancillary equipment, warranty provisions, Government furnished property/equipment, testing, etc.).

Schedule Change - A change in a delivery schedule, completion date or intermediate milestone of development or production.

Unpredictable Change - A change caused by Acts of God, work stoppage, Federal or State Law changes or other similar unforeseeable events. Unforeseeable events include extraordinary contractual actions under the authority of PL 85-804 except that formalization of informal commitments should be reflected under the other categories, as appropriate and not included under this category.

Economic Change - A change due to the operation of one or more factors of the economy. This includes specific contract changes related to economic escalation and the economic impact portion of contract quantity changes computed using the original contract cost-quantity relationship. This also includes changing real dollar amounts in program estimates to reflect (1) revised economic impact or (2) definitized contract amounts.

Estimating Change - A change in program or project cost due to refinements of the base estimate. These include mathematical or other errors in estimating, changing the base year of the constant dollars, revised estimating relationships, changing from constant dollars to real dollars, etc.

Contract Performance Incentives - A net change in contractual amount due to the contractor's actual performance being different than was predicted by performance (including delivery) incentive targets; as differentiated from cost incentive targets; established in an FPI or CPIF contract. This category also includes any changes in amounts paid or to be paid a contractor due to (1) award fee for performance accomplishments under a cost plus award fee contract or (2) the sharing provisions of a value engineering incentive clause included in any type of contract.

Contract Cost Overrun (Underrun) - A net change in contractual amount over (under) that contemplated by a contract target price (FPI contract), estimated cost plus fee (any type cost reimbursement contract) or redeterminable price (FPR contract), due to the contractor's actual contract costs being over (under) target or anticipated contract costs, but not attributable to any other cause of cost growth previously defined. Offsetting profit or fee adjustments attributable to cost incentive provisions, if any, shall be considered in determining the net contract cost overrun (underrun).

Expenditure - A monetary liability incurred for goods or services received or assets acquired through contractual methods and payment made.

Expense Item - An unrecoverable or non-repairable type item; an item that is normally discarded after its service life is exceeded or if found to be defective. Reference Investment Item.

Group "A" Kit - The items, parts, or components to be permanently or semipermanently installed in a Configuration Item to support, secure, interconnect, or accommodate the equipment provided in the retrofit change Group B kit. (AFR 57-4)

Group "B" Kit - The equipment which, when installed in a Configuration Item with a Group A kit, completes a retrofit change. Normally, Group B items are removable. (AFR 57-4)

Industrial Priority Rating - A ranking of contract precedence; the rating assigned to a Government contract establishes the degree of precedence industry must, by law, give to its execution in relation to other contracts. There are two ratings: DX and DO; DX has the highest national priority and ranks over DO rated and unrated contracts.

Initial Provisioning - The process of determining the range and quantity of spare and repair parts required to support and maintain new systems and equipment during their initial period of operation.

Initiation - The submission to the accounting activity of a purchase request for the procurement of material or services where it is recorded in the accounting records as part of the coordination cycle of the purchase request.

Inspect and Repair As Necessary (IRAN) - A program that schedules contractor or depot facilities or teams for the accomplishment of maintenance on aircraft and missiles not included under the modernization program.

Inventory Manager (IM) - The AFLC AMA with management responsibility for commodity-type items by Federal Supply Class. (AFR 57-4)

Investment Item - A recoverable or repairable type item; an item that is normally repaired and put back into serviceable assets. Also called a replenishment type item. Reference Expense Item.

#### Life Cycle Cost Element Categories

Acquisition Cost - The sum of the unit prices for the line items of hardware, data, and services being procured.

Initial Logistics Cost - The one-time logistics costs which are identifiable and would be incurred by the Government for the item being procured.

Recurring Cost - The cost incurred by the Government in connection with the operation, maintenance, and management of the item being procured.

Modification - A change which: (1) Is temporary and necessary to accomplish a special mission for a special purpose; (2) Satisfies a requirement for testing or production continuity; (3) Corrects a deficiency revealed after transfer of retrofit change responsibility from AFSC to AFLC; or (4) Satisfies a requirement for a new capability that is determined after the CI product base line has been established. (AFR 57-4)

Obligation - Commitments made by Federal agencies to pay out money for products, services or other purposes-- as distinct from the actual payments. Obligations incurred may not be larger than the budget authority.

Over and Above Work - Repair, replacement or other work performed by a contractor on Government owned equipment which is 'over and above' the originally specified work requirement. Corrects deficiencies uncovered in performance of specified task, and is usually authorized only to remove a safety-of-flight deficiency or when deemed to be in the best interest of the Government.

Procurement - Includes purchasing, renting, leasing, or otherwise obtaining supplies or services. It also includes all functions that pertain to the obtaining of supplies and services, including description but not determination of requirements, selection and solicitation of sources, preparation and award of contract, and all phases of contract administration. (ASPR)

Procurement Authorization (PA) - The authority to prepare a purchase request and release to the procurement organization for negotiation up to, but not including, commitment of funds. Reference Budget Authorization.

Retrofit Change - A configuration change that is accomplished after production delivery. The term includes modifications and updating changes. (AFR 57-4)

Stock Fund - A working-capital fund established to provide a simplified means of financing and accounting for the purchase, holding and sale of common use items.

Systems Support Manager (SSM) - The AFLC AMA organization delegated the overall management responsibility for a given weapon system and its complete integrated support posture.

Time Milestone (T<sub>m</sub>) - An established point in the chronology of a modification program.

APPENDIX B  
C-130 CENTER WING PROGRAM

## APPENDIX B

### C-130 CENTER WING PROGRAM

This appendix presents a chronological accounting of the total C-130 Center Wing Program. The program was conceived to permanently eliminate fatigue cracks in the center wing section of C-130 aircraft. There is one HQ USAF directed Class IV modification, No. 10009, in the program. This modification is for the development, fabrication, and installation of a new center wing box beam structure. The fatigue cracked, old center wing box beam is replaced under Modification 10009 by the new structure at the Lockheed-Georgia Company under an Air Force contract let by the Warner-Robins Air Materiel Area.

The C-130 Center Wing Program has many facets. Discussion of these other aspects is necessary to understand the role of Mod No 10009, and to serve as a basis for discussions in other sections of this thesis. Figure B1 presents a program summary. The summary spans nine fiscal years and depicts the program as it had occurred and was envisioned as of September 1970. Besides the aircraft modification, the program encompasses inspections of the aircraft, development and installation of repair kits, engineering tests and data gathering

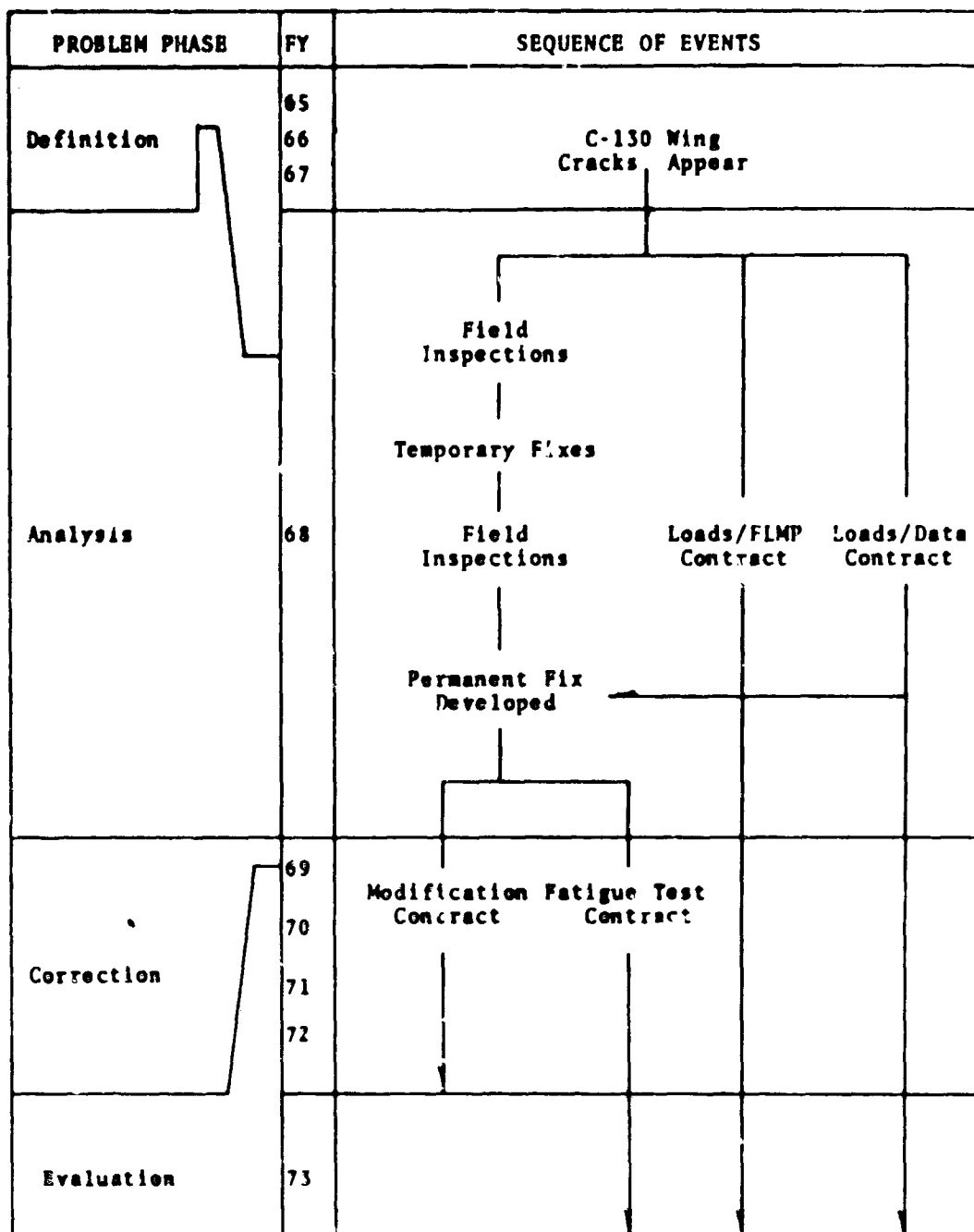


Figure B1. C-130 Center Wing Program Summary.

programs. There are six contracts related to this program, two of which are follow-on efforts. These contracts and their relationship to the total program will be the subject of subsequent sections in this Appendix.

### Background

The C-130 is a cargo/transport aircraft, powered by four turboprop engines, developed and produced for the USAF by the Lockheed-Georgia Company, Marietta, Georgia. It has been in production since 1952 and as of September 1970 more than 1100 have been manufactured. There are currently 29 models and 45 versions of this aircraft. Although the primary mission of the USAF C-130 is tactical airlift, other models and versions have been manufactured for a variety of military missions such as command and control, search and rescue, and air-to-air refueling. In addition, the US Navy, Coast Guard, civilian companies and foreign governments have purchased C-130 aircraft. The System Support management functions for C-130 aircraft are the responsibility of the Warner-Robins Air Materiel Area (WRAMA), Robins AFB, Georgia.

The C-130 aircraft wing structure is in three parts: a center wing and two outer wings. The center wing box beam comprises the middle portion of the center wing which is attached to the upper part of the



fuselage. Two of the four turboprop engines are attached to the center wing. Fixed to the center beam are the outer wings, right and left, with the remaining engine assemblies.

The C-130B and C-130E model aircraft represented a technological advance over the earlier C-130A model by providing for an increase in range, payload and fuel capacity to meet new operational requirements. The increased fuel capacity was achieved by adding fuel cells to the center wing cavity. This change necessitated fuel filler neck cut-outs, access doors, and the installation of internal doublers and I-beams to restore load carrying capabilities. These changes resulted in areas of high stress concentrations which later led to cracking in the cut-out areas and in the associated backup structure.<sup>1</sup>

The first fatigue failure occurred in February 1965 at an upper wing panel fuel filler neck on a fatigue test article at the Lockheed-Georgia Company, hereafter referred to as Lockheed. The fatigue test program, contracted for by the Aeronautical Systems Division (ASD) of the Air Force Systems Command (AFSC), was designed to determine the fatigue endurance of the C-130 aircraft and its components. First cracking of C-130 fleet airplanes was reported in early 1966. Inspections and field fixes were made on these aircraft. The fatigue

test articles at Lockheed also predicted failure of other areas at various flight hours. However, no failures were discovered in the C-130 B/E force in 1966.<sup>2</sup>

In January 1967 cracks in the lower surface of the center wing of a fleet airplane were observed. However, during the period February 1965 through July 1967 sample inspections on the operational fleet reported negative findings other than noted above. In the 1966-1967 time frame Lockheed had performed engineering tasks for WRAMA Service Engineering to design and test upper and lower wing surface repairs. In August 1967 cracks of 3"-5" were discovered in a Pacific Air Force (PACAF) C-130 aircraft receiving IRAN (Inspection and Repair As Necessary). Sample inspections of C-130 in WRAMA IRAN facilities confirmed the need for immediate inspection of the entire C-130 force.<sup>3</sup>

In June 1967, Lockheed representatives approached HQ USAF personnel desiring to apprise the Air Staff of fatigue test program results and requesting to brief the Air Lift Panel. HQ USAF directed that the presentation first be given to Headquarters, Air Force Logistics Command (HQ AFLC) and WRAMA. The Lockheed briefing to HQ AFLC was based on statistical data regarding Southeast Asia (SEA) operations and information obtained from fatigue tests. Lockheed was recommending that consideration be given to a new center wing section and a new landing gear to enable the C-130 to continue assault missions through the 1970s. Lockheed also recommended

consideration of a flight safety technical order to inspect the fleet. WRAMA did not concur in the Lockheed position regarding safety of flight and structural integrity since they did not believe the data was factual. Lockheed briefed HQ TAC (Tactical Air Command) on 21 June 1967 on this subject. Between 21 June 1967 and early August 1967 Lockheed gathered more factual data regarding the assault type mission of the USAF C-130. This effort culminated in Engineering Test Proposal (ETP) 749, Modified C-130E Advance Assault Program, dated 21 August 1967. Lockheed briefed WRAMA on this ETP on 23 August 1967. HQ AFLC, HQ TAC and HQ PACAF had heard of the study and requested briefings, but the latter two were never held.<sup>4</sup>

ETP-749 proposed modification of the C-130E airplane by installation of high flotation landing gear, a new center wing and a fuel transfer system. The ETP also raised serious questions as to the economic safe life of the airplane structure if the airplane continued to operate in the SEA environment, which was quite different from that for which it was designed. WRAMA took exception to the severity of SEA operations expressed by Lockheed.<sup>5</sup>

#### Inspection and Repair

The AFLC Commander was briefed on the fatigue problem by WRAMA on 1 September 1967. As a result, Technical

Order 1C-130-798, dated 12 September 1967, was published to inspect specified areas of the center wing for cracks on all series C-130A, C-130B, C-130D and C-130E aircraft using dye penetrant and black lights. Contracts were awarded to Lockheed Air Service and Lear Seigler Incorporated to participate in conjunction with depot field teams from WRAMA to accomplish this inspection at bases where these C-130 aircraft were assigned. All aircraft in WRAMA IRAN facilities were inspected concurrently with IRAN.<sup>6</sup> From 15 September 1967 to 10 November 1967, out of 587 aircraft inspected, 276 were found to have cracks. Reinspection of aircraft with cracks was directed by the AFLC Commander to determine the rate of propagation and confirm earlier inspections. This was completed in January 1968. Inspection intervals were established to keep track of the fatigue crack problem in the C-130 fleet. By June 1968, 388 aircraft were found to have a total of 6,187 cracks, of which 450 were 1/8" or greater. The 388 aircraft were comprised of 8 C-130A, 105 C-130B, 268 C-130E and 7 HLC-130H.<sup>7</sup>

Repair crack criteria were established and temporary repairs effected. AFLC purchased repair kits on a limited basis from Lockheed pending a decision on a permanent fix. Engineering Change Proposal (ECP) 912 kit was for repair of the upper surface of the center wing; ECP 939 kit was for the repair of the lower surface, and

ECP 941 kit for the spar. The kit nomenclature of ECP stems from the Engineering Change Proposals Lockheed submitted to the Air Force to manufacture and deliver these kits. As of May 1968 the inspection effort had cost approximately one million dollars.<sup>8</sup> The inspection of an aircraft and the installation of repair kits as necessary were in effect until the aircraft received a new center wing.

#### Analysis

Concurrent with the inspection effort, a C-130 Control Center and five working panels were established by WRAMA effective 1 September 1967. The center and panels, with membership from various Air Force and industry groups, was charged with monitoring the inspection and repair effort, collecting and analyzing historical environmental and current operational data on C-130 aircraft, and determining and analyzing corrective hardware changes. A C-130 Loads Measurement Program was the task of Panel IV. Since the work of this panel involved four of the six contracts mentioned earlier, it will be dealt with in more depth in subsequent paragraphs.

The studies conducted by the various panels were essentially completed by March 1968. They identified the accelerated fatigue damage problem as being primarily,

but not solely, caused by the environment the airplanes are exposed to in the SEA operation. The C-130 Loads Program identified the ground operation, taxi, take-off, landing, and roll as the most damaging.<sup>9</sup>

The C-130 Loads Measurement Program could be described as two concurrent programs or phases. The first phase consisted of establishing an air/ground environmental loads program to determine the quantitative loads being transmitted to the airframe during the ground environment under all present runway conditions. This phase had five tasks: (1) The Limited Loads Program (Quick Look) which was designed to confirm as early as possible the operating stress levels produced by SEA environment, (2) The Environmental Loads Recording and Analysis Program (ELRAP) which was established to provide and define SEA operational data on a continuing basis, (3) The VGH Program to verify and supplement the mission profiles and operational usage of the C-130 fleet, (4) The Taxi-Air-Ground (TAG) Program to serve as the baseline for all of the environmental loads programs, and (5) the Airfield Data Program to define airfield characteristics. The second phase of the C-130 Loads Measurement Program was to establish and implement an 'Equivalent Hour' program to permit assessing the fatigue damage which accrues to each airplane resulting from its daily operational use.<sup>10</sup> The fleet inspection

data described in the previous section and the above five tasks of the first phase were to provide input to this 'E-Hour' Program.

Two contracts were initially awarded to industry in connection with the C-130 Loads Measurement Program. These contracts were F09603-68-C-1397 with Technology, Inc., Dayton, Ohio and F09603-68-C-1335 with the Lockheed-Georgia Company, Marietta, Georgia.

Contract F09603-68-C-1335 with Lockheed was in effect as of 17 January 1968.<sup>11</sup> A letter contract provided for Lockheed to provide specialized engineering services required to accomplish the following four contract items: (1) Fatigue Life Monitoring on C-130 aircraft, (2) C-130 Taxi-Air-Ground (TAG) Program, (3) Phases II and III of the Environmental Loads Recording and Analysis Program (ELP) and Quick Look Program (QLP), and (4) C-130 Airfield Data Measurement Survey (AD). Work specifications described the actions required under each contract item above. The letter contract, dated 1 May 1968, obligated \$1,267,294.50 and contemplated a Cost Plus Fixed Fee (CPFF) type definitive contract within 155 days. Contract Modification P003, 13 November 1968, definitized the letter contract into a CPFF type at a total price of \$5,257,772. The cost and fee break-out by contract items is shown in Table 1B.

Table 1B  
Cost/Fee Breakout for Contract F09603-68-C-1335

Contract Item Nr.	13 November 1968			3 September 1970		
	Est. Cost	Fixed Fee	Total	Cost	Fee	Total
1	1,279,497	108,757	1,388,254	2,182,492	175,136	2,357,628
2	2,142,784	182,137	2,324,921	2,285,807	189,114	2,474,921
3	1,400,550	119,047	1,519,597	1,394,641	118,545	1,513,186
4	25,000 <sup>1</sup>	---	25,000	29,708	---	29,708
Total	4,847,831	409,941	5,257,772	5,892,648	482,795	6,375,443

Note 1. Contract Item 4 was terminated; \$25,000 allowed for termination costs.

Source: Official Contract File, WRAMA(PPCA).



Contract F09603-71-C-0700, awarded 6 August 1970 to Lockheed continued the purchase of specialized engineering services required to accomplish the Fatigue Life Monitoring Program on C-130 aircraft through 30 June 1971. It is a CPFF type and contains an option to extend it through FY 72. The estimated costs and fixed fees are shown in Table 2B.

Table 2B  
Cost/Fee Breakout for Contract F09603-71-0700

	FY 71	FY 72	Total
Estimated Cost	\$829,493	641,747	1,471,240
Fixed Fee	<u>70,507</u>	<u>54,548</u>	<u>125,055</u>
Total	\$900,000	696,295	1,596,295

Source: Official Contract File, WRAMA (PPCA)

To summarize, if the above costs and fees hold, the FY 72 option exercised, and the final figures on Contract-1335 remain approximately the same, the total estimated price for all these specialized engineering services from Lockheed will be \$7,971,738.

Technology, Inc. was authorized by WRAMA on 17 January 1968 to proceed on Contract F09603-68-C-1397

to provide contractor services to conduct a velocity, accelerometer loads altitude recorder program on C-130 aircraft.<sup>12</sup> This effort is associated with the VGH Program described in Task 3 of the Loads Measurement Program. The price of this CPFF type contract through FY 70 and Contract Modification P004 was \$970,836. Contract F09603-70-C-1825 continues this effort in FY 71 at an estimated price of \$747,438. Thus the total estimated price of the Technology, Inc. effort is \$1,718,374.<sup>13</sup>

#### Modification Program

This section presents a chronological history of that part of the C-130 center wing program which deals with the actual modification, i.e., replacement of the center wing box beam structure and associated components on fleet C-130 aircraft. Also included is a discussion of the new C-130 fatigue test program. Two contracts are involved, F09603-68-C-2530 for the modification, and F09603-68-C-2956 for the fatigue test program.

The fleet inspection effort and the work of the C-130 Control Center and Panels continued during the fall of 1967. A C-130 Structural Problem meeting was held at HQ AFLC on 19 December 1967. The objective of this meeting was to assess reinspection results and analysis, and to determine the future course of action on the program.<sup>14</sup> HQ AFLC, ASD, WRAMA and Lockheed

representatives attended. The meeting resulted in the continuation of inspections, establishment of inspection intervals, an expanded analytical inspection program, direction to pursue portions of the loads measurement program as rapidly as possible, as well as testing of a landing gear modification. The inspections and installations of repair kits would assure structural integrity until the most appropriate long term solution could be determined. When the expected lifetime of the aircraft and its continuing mission as an intra-theater assault transport were considered, it was indicated that there was a likelihood that the most appropriate long term solution would involve structural changes to reduce stress levels in the center wing. A rough preliminary estimate for this course of action was given as approximately \$125,000,000. over a three year period beginning in FY 69.<sup>15</sup>

The work of the Control Center, Panels and other WRAMA organizations culminated in briefings at HQ AFLC and HQ USAF on 28 March 1968 and 3 April 1968 respectively. The briefings included a review of inspection findings, the loads measurement program, an analysis of possible fixes and recommendations. The briefings were based in part on information supplied by Lockheed in its ETP 782, forwarded to WRAMA on 5 February 1968. It constituted the Best Estimate (BE) available and was jointly arrived at by WRAMA and Lockheed.

Some of the significant briefing facts follow:<sup>16</sup>

1. As of 15 March 1968, 338 of 688 C-130 aircraft in the inventory had cracks: 97 of 117 C-130B, 230 of 309 C-130E and 11 of 262 other C-130 models.

2. Four alternative fixes were considered as most feasible and presented:

- a. Doubler repairs (ECPs 912 and 939).
- b. Replace panels with C-130K design.
- c. Replace panels with an improved design.
- d. New center wing box beam.

3. Recommendations.

- a. Procure the landing gear modification contingent on test results.
- b. Procure new center wing.
- c. Procure fatigue test program for new center wing.
- d. Procure ECP kits as necessary pending wing modification.

4. If the above recommendations were approved, costs for the four fiscal years were to be as shown in Table 3B, with a total program cost of \$77.8 million.

5. The schedule details of the briefing are also shown in Table 3B. The details were based on a contract go-ahead of 1 April 1968. A work day flow time of 21 days per aircraft, which equates to about 30 calendar days based on a 5 day work week, was estimated. The unit cost was estimated at \$0.176 million/aircraft.

Both HQ AFLC and HQ USAF approved the recommendations as presented. However, HQ USAF requested an Advanced Procurement Plan (APP) in accordance with ASPR,

Table 3B  
Estimated Costs/Schedule,<sup>1</sup> WRAMA Briefing

Task	FY 68	FY 69	FY 70	FY 71	Total						
Landing Gear <sup>2</sup>		0.6			0.6						
New Wing <sup>2</sup>	3.9	18.7	29.6	18.9	70.6						
Over & Above		0.8	1.9	1.4	4.1						
Fatigue Test	0.5	1.0	0.5	0.5	2.5						
Total	4.4	20.6	32.0	20.8	77.8						
-----											
Fiscal Year	FY 69				FY 70	FY 71					
Quarter	1	2	3	4	1	2	3	4			
Acft In	1	6	30	45	45	45	45	45	3		
Acft Out		4	19	44	45	45	45	45	18		
Cum Out		4	23	67	112	157	202	247	337	382	400

Note 1. Cost units are dollars (\$) in millions; schedule units are numbers of aircraft.  
 Note 2. Tasks are based on 400 aircraft total.  
 Source: WRAMA Briefing for AFLC Commander, C-130 Center Wing Problem, 28 Mar 1968.

directed the program to proceed to procure and install the new center wing assembly on all C-130B/E aircraft, and accepted the budgetary estimate of \$77.8M for the total program for planning purposes. Refined costs and schedules were to be made available as soon as possible.<sup>17</sup>

(Researcher's Note on the 28 Mar 68 Briefing. The schedules and costs were based on 400 aircraft, but the inventory contained 426 C-130B/E aircraft. In addition, 62 HC-130H/P aircraft were in the inventory, and some H models had been found to contain cracks. The 21 workday flow time was at steady state; longer times were anticipated during startup. A warranty for the new center wing was offered by Lockheed and contemplated by WRAMA, but not priced. Mutual agreement had not been reached on terms and conditions. If the totals for the new center wing and 'over and above' costs are summed, the total cost is \$74.4M.)

The APP was approved by the WRAMA Commander on 11 April 1968<sup>18</sup> and presented to HQ AFLC and HQ USAF in written and briefing form on 24 and 25 April 1968 respectively. The significant variations from the 28 March 1968 briefing are listed below.<sup>19</sup>

1. The plan discussed only the center wing modification for 400 aircraft; no costs were given for the fatigue test program, landing gear modification, or warranty.

2. The plan was predicated on a 1 June 1968 contract award.

3. The schedule shown in Table 4B could be achieved only if a DX priority rating was obtained on long lead time items.

4. First aircraft input for modification would be output in 32 workdays with 21 workdays reached on the twelfth aircraft.

5. Note was made in the plan that the Navy had 66 C-130 aircraft and the Coast Guard 13 C-130 aircraft which could be added to the program.

6. A single contract would be used for the total procurement; a letter contract to be issued initially, later to be definitized as a Fixed Price Incentive Successive Targets (FPIS) type.

7. Lockheed was to be requested to include an appropriate warranty provision in their proposal.

8. The Fiscal Year funding by Budget Program (BP) was as in Table 4B. Included in these figures are the \$4.1M for 'over and above' work.

Approval of the APP by HQ USAF was received on 26 April 1968; however WRAMA was directed to consult with ASD on the contract type and with JAMAC relative to securing materials without a DX rating.<sup>20</sup>

In this time period an AFLC Form 48, a Configuration Control Board (CCB) Item Record, for the center wing

### Table 4B

**Source: Advance Procurement Plan**



modification and beef up of the upper rib caps on both outer wings was submitted for record purposes only. It was approved by the WRAMA CCB on 12 April 1968 and by the AFLC CCB on 24 April 1968. Costs, schedules and other information were the same as the APP.

Modification Program Directive (MPD) No. 10009 was issued by HQ USAF on 15 May 1968. Significant changes from the APP or noteworthy items are listed below.<sup>21,22</sup>

1. A DO industrial priority rating was authorized.
2. Four hundred (approx) C-130B/E aircraft in the USAF active inventory were to be modified according to the DX schedule in the APP (Table 4B).
3. Flow times were not to exceed 30 calendar days when the schedule reached 15 aircraft per month.
4. No peculiar or additional AGE were to be required; first year spares (FY 69) in an estimated amount of \$43,100 would be required.
5. No BP 15400 funds were approved, other funds were approved as in the APP; total equalled \$74.7M. Reference Table 5B.
6. A cyclic fatigue test program, at an estimated cost of \$3.4M was to be accomplished with multiyear funding in the AFLC Aircraft Structural Integrity Program (ASIP).

7. The procurement contract would include and appropriate fatigue life design warranty for the new center wing, which would be tied to the cyclic fatigue test program.

During May and June 1968 negotiations were in progress for award of letter contracts on the modification and fatigue test programs. Now, this chronological history will separate the two programs. The wing modification will be covered first.

A letter contract, F09603-68-C-2530, was issued to Lockheed on 13 June 1968 obligating \$3,860,000. The contract was for the engineering, design, fabrication, installation, data and spares of a modified center wing applicable to the C-130B/E aircraft. The contract contemplated a FPIS or Fixed Price Incentive Fixed Fee (FPIF) type contract to be definitized within 180 days. The contemplated schedule was 52 aircraft (input) in FY 69, 180 in FY 70 and 168 in FY 71. This schedule was contingent on the Government providing the contractor with a DX rating.<sup>23</sup> Work was to be accomplished in accordance with engineering specification WRNEAS 68-22-C130 until the Lockheed Engineering Report ER/P-9262 was approved. This ER/P was originally dated 30 Apr 68, then revised on 23 May 68, 28 Jun 68, and 17 Dec 68. The landing gear modification was never procured as the design became more complex and expensive.

The letter contract was definitized by Contract Modification P207, dated 31 July 1969, and will be discussed later. In this time frame of June 1968 to July 1969 contract change orders obligated an additional \$23,153,001 in order to obtain long lead time items and avoid work stoppages, provide funds for fabrication and installation of outer wing rainbow fittings to be discussed below, and to change the quantity of FY 69 and FY 71 aircraft from 52 to 53 and 168 to 167 respectively.<sup>24</sup> Also, the first aircraft was input on 14 November 1968 and output on 5 February 1969.

In-service and fatigue test article failures identified the wing joint (center to outer wing) as fatigue sensitive in addition to the upper and lower surfaces of the center wing section noted earlier. The APP and MPD costed for and recognized that changes to the center wing fitting, commonly and hereafter referred to as the 'rainbow fitting' because of its shape, would be necessary to improve the fatigue resistance of the fitting. These changes included reprofiling, shotpeening and finish change. However, in order to maintain the integrity of the wing joint, new rainbow fittings are also necessary on the outer wings.<sup>25</sup> The original modification program and original statement of work did not include replacing the outer wing rainbow fittings.<sup>26</sup> The replacement of the outer wing rainbow fittings could

be accomplished during depot level, scheduled maintenance, however additional IRAN maintenance funds would be required since engine and wing removal was not required under the IRAN program, in effect at that time, for all aircraft. Additional downtime for the aircraft would also occur. However, this expenditure of time and IRAN funds could be saved by having Lockheed perform this effort at the time the outer wings were removed from the aircraft for the center wing modification. This effort was contemplated by WRAMA as early as April 1968.<sup>27</sup> The Lockheed work specification was changed 17 December 1968 to incorporate this additional work.<sup>28</sup> An AFLC Fm 48 for outer wing rainbow fittings to modify 370 aircraft was presented to HQ AFLC by WRAMA on 12 February 1969, after the D-17 report, as of 31 Dec 68, reflected a cost increase for Mod No 10009; a cost increase which Lockheed indicated would be \$17,921,687. The AFLC Fm 48 was held in abeyance by HQ AFLC because of the attendant price increase.<sup>29</sup> While WRAMA sought alternative methods of accomplishment, Lockheed had placed an order with the Rohr Corporation for the rainbow fittings and \$325,000. had been expended.<sup>30</sup> After considerable involvement and discussion among HQ USAF, HQ AFLC, WRAMA and Lockheed personnel, a briefing by WRAMA to HQ AFLC on 21 April 1969 resulted in approval of the installation of outer wing

rainbow fittings by Lockheed. This approval was to be officially granted when WRAMA submitted a Form 48 for a new Class IV modification.<sup>31</sup> A new AFLC Fm 48, Installation of Improved Outer Wing Rainbow Fittings, C-130B/E Acft, was approved by the WRAMA CCB on 12 May 1969 and by HQ AFLC CCB on 28 May 1969. This modification did not need HQ USAF approval since it was not identified to Mod No 10009, and the cost for any fiscal year was not greater than five million dollars. The total approved cost was \$8,040,952; by fiscal year; FY 69 = \$1,191,865., FY 70 = \$3,614,241., FY 71 = \$3,234,846. The program covered the installation of improved fatigue resistant outer wing rainbow fittings on 400 aircraft concurrent with center wing modification No 10009.<sup>32</sup> The first outer wing rainbow fittings were incorporated on aircraft number C046 which was input 13 June 1969. At this same time discussion ensued about replacement of engine truss mounts concurrently with the outer wing rainbow fitting replacement. Since it was never approved by HQ AFLC, it will not be discussed in this study.

Other major issues during this time period involved the contract warranty provision, spares, and reimbursement for Government Furnished Material (GFM) from the Depot Maintenance Industrial Fund (DMIF). An AFLC Fm 48 was submitted to HQ AFLC by WRAMA on

12 February 1968 for a cost increase of \$5,870,000 for warranty (\$2.2M), fatigue test (\$1. . . ) and GFM (\$2.2M). The reasons given for the cost increase were<sup>33</sup> that although the initial program (MPD, 15 May 1968) established a requirement for warranty, terms and costs were then unknown and thus unfunded; the initial program did not include funds for GFM; beginning 1 July 1968 operation under DMIF had commenced. The \$2.2M for GFM was established based on a contractor billing of \$11,000 for two aircraft, i.e., 400 acft X \$5,500. The fatigue test portion will be discussed later. The HQ AFLC CCB held the Form 48 in abeyance awaiting clarification and re-validation. Because of the attendant cost increase, pressures to remain within program funding,<sup>34</sup> and funding problems,<sup>35</sup> the 21 April 1969 briefing (reference rainbow fittings) by WRAMA at HQ AFLC resulted in the warranty being deleted and a new Form 48 to be submitted. The new Form 48 was approved by WRAMA on 12 May 1969 for a cost increase of \$2,602,396 for GFM (\$2.2M) and spares (\$0.4M) not previously identified. The HQ AFLC CCB did not approve the Form 48 until 27 August 1969 after contract definitization.

The letter contract, L/C F09603-68-C-2530, was definitized by Contract Modification PZ07, 31 July 1969. Contractor cost proposals, Government field analyses and audits were submitted and negotiations conducted

from August 1968 on. The definitive contract was negotiated as a FPIF type, 70/30 sharing, 119% ceiling, 10.5% profit, at a total target price (TTP) of \$79,630,709. Recall that the letter contract was based on 400 aircraft. A need existed, prior to negotiation, to increase the FY 71 option by 12 aircraft from 167 to 179 to cover 12 Coast Guard aircraft.<sup>36</sup> Thus, the definitive contract was for the modification of 412 aircraft.

As of September 1970 there were 23 change orders on this contract. The first six, P001-P006, were incorporated into the definitive contract by P207. A brief description of the remaining changes is provided.<sup>37</sup>

P008-15 Aug 69: An administrative change of contract item numbers on an accounting document.

P009-8 Dec 69: Allows substitution of 3 Coast Guard aircraft for 3 USAF aircraft in FY 70; total obligation increased to \$57,213,141; USAF obligation decreased by \$551,220., USCG set at \$617,520., difference is due to additional USCG money for over and above work.

P010-3 Dec 69: Increases the amount of USAF FY 70 funds obligated for over and above (Contract Item 5) and material support (Contract Item 5AB) by \$987,000.

P011-21 Jan 70: Change in work scope: aircraft input with H-type wing, should have E-type wing. Reference P020.

P012-24 Mar 70: Specification change note (SCN) 10 and 11 added to ER/P-9269. Schedule adjustments made at no cost.

P013-27 Feb 70: Allows substitution of 3 more USCG aircraft for 3 USAF aircraft in FY 70; no change in total obligation, but increase in USCG obligation of \$575,404 and corresponding decrease in USAF obligation.

P014-12 Feb 70: Same problem as P011.

P015-26 Feb 70: Incorporates provisions for furnishing special production tooling and test equipment as Government Furnished Equipment (GFE) to Lockheed at no change in price.

P016-13 Mar 70: Allows for expedited delivery of six spare parts at no change in price.

P017-15 Apr 70: SCNs 12 and 13 to ER/P-9269 added; schedule adjustments made at no cost.

P018-16 June 70: Accelerates schedule; 5 aircraft from FY 71 moved into FY 70. additional USAF obligation of \$944,860 made.

P019-1 Jul 70: Exercises FY 71 option to modify center wing on 174 C-130 B/E aircraft in FY 71; obligates an additional \$24,340,385.

P020-20 Jul 70: Definitizes P011 and F 14 and results in deobligation of \$19,018.

P021-21 Aug 70: Incorporates a revision to work specification on over and above items at no change in price.

P022-(In negotiation): For supplies and services to accomplish engineering, fabrication, installation, data and spares for installation of fatigue sensors in the wings of 80 C-130B/E aircraft. Price estimated at \$498,300.

P023-4 Sep 70: Obligates an additional \$420,000. for the switch of 42 aircraft in FY 71; replaces the planned 42 USAF C-130B/E aircraft with 25 USAF HC-130H/P and 17 USN KC-130F and EC-130G/Q aircraft. The actual price to be negotiated later.

It should be noted that the USCG paid for their six aircraft on this USAF contract via direct cite. The USN will reimburse USAF, since they requested this modification via a Military Interdepartmental Purchase Request (MIPR). As of September 1970 the USCG had obligated \$1,126,624 and the USN had provided USAF \$2,714,000 via MIPR.

By December 1969 WRAMA engineering approval had been given on performing the center wing modification



and installation of the improved outer wing rainbow fittings on 60 USAF HC-130H and HC-130P aircraft assigned to the Military Airlift Command (MAC).<sup>38,39</sup> Eleven HC-130H/P aircraft had experienced center wing panel cracks. AFLC Fms 48 for this effort were approved at WRAMA on 26 March 1970 and HQ AFLC on 8 April 1970. The cost for the center wing modification was estimated at \$10,723,085. and for the outer wing rainbow fittings at \$1,249,160. Twenty-five aircraft were scheduled in FY 71 and 35 in FY 72. The HC-130H/P modification was not approved since the problem had not become critical on those aircraft. The modification had to be accomplished at this time while all necessary tooling was available.<sup>40</sup> HQ USAF issued MPD Amendment 1 to Class IV Mod No 10009 on 15 May 1970. This amendment increased funds on Mod No 10009 by \$10,723,085 to \$88,025,481; thereby including the modification of 60 HC-130H/P aircraft starting in July 1971 and completing in March 1972.<sup>41</sup> Recall at this point that the outer wing rainbow fittings are not associated with Mod No 10009.

At the time this research was conducted there were no apparent, current problems of any significant magnitude. Minor input/output schedule problems were occurring, as were other administrative 'fire-fighting' details, but major program fluctuations were not present nor predicted.

The next two paragraphs of this chronological history deal with the fatigue test program for the C-130 aircraft with a new center wing. Recall that the briefing of 28 March 1968 and the APP and MPD contemplated a fatigue test program. The estimated cost of this program in the MPD of 15 May 1968 was \$3.4M, and was based on figures in Lockheed's ETP 790.

A letter contract, F09603-68-C-2956, was awarded to the Lockheed-Georgia Company on 29 June 1968. This contract, sometimes referred to as the 'shaker contract,' required the contractor to (1) fabricate a new test specimen, fuselage barrel and center wing, (2) conduct a test for four lifetimes or 40,000 test hours, which equates to 10,000 flight hours, and (3) design and test all required repairs. The letter contract for these specialized engineering services and data for the C-130B/E full scale fatigue test obligated \$250,000. Change Order P001, 5 March 1969, obligated an additional \$218,672. The contract was definitized by P202 on 28 May 1969 as a Cost Plus Incentive Fee (CPIF) type and the total obligation was raised to \$1,485,216. Change Order P003, 15 July 1969, exercised the FY 70 option and obligated an additional \$669,000. All other contract changes were minor and/or related to repair of the test article except P011, 15 July 1970, which exercised the FY 71 option. As of P011 the total price, cost plus fee, was

\$2,791,179. This price funds the fatigue test program through FY 71, except for any costs incurred for repairing the test article due to test failures. The estimated prices in the contract for FY 72 and FY 73 options are \$340,000 and \$31,000 respectively.<sup>42</sup>

### Summary

This section summarizes the cost, schedule and performance aspects of the C-130 Center Wing Program with emphasis on Mod No 10009 and Contract F09603-68-C-2530. The summary is as of September 1970 when the data were collected; it recaps data presented in the previous sections. Future projections are made where appropriate. This section also contains some observations and thoughts of the researcher.

### Cost

Costs may be viewed in many different lights. The figures can be made to reflect whatever point of view is desired. Table 5B shows the incremental and cumulative amounts approved by HQ USAF and HQ AFLC. The approved HQ USAF total is \$88,025,481; the HQ AFLC total is \$97,315,593. An estimated total for all Military Services is \$108,515,593. Table 6B shows the incremental and cumulative obligations, as of September 1970, on Contract C-2530. Also shown in Table 6B are the cost

Table 5B  
Cost Track - Approved

<u>HQ USAF Approved (MPD)</u>		<u>Cumulative</u>
15 May 68 =	\$74,700,000.	\$74,700,000.
19 Sep 69 =	2,602,396.	77,302,396.
15 May 70 =	10,723,085	88,025,481.
<u>HQ AFLC Approved (AFLC Fm 48)</u>		
<u>Center Wing Modification</u>		
24 Apr 68 =	\$74,700,000.	\$74,700,000.
27 Aug 69 =	2,602,396.	77,302,396.
8 Apr 70 =	10,723,085.	88,025,481.
<u>Rainbow Fitting Modification</u>		
28 May 69 =	\$ 8,040,952.	\$ 8,040,952.
8 Apr 70 =	1,249,150.	9,290,112.
<u>AFLC Total Approved</u>	\$97,315,593.	
<u>USAF/USN/USCG Approved</u>		
USAF	\$97,315,593.	
USN (est. 40 @ \$0.2M/acft)	8,000,000.	
USCG(est. 16 @ \$0.2M/acft)	3,200,000.	
Total (est)	\$108,515,593.	

Table 6B  
Cost Tracks - Contract F09603-68-C-2530

<u>Total Obligated<sup>1,2</sup></u>	<u>Incremental Obligation</u>
L/C - 13 Jun 68 = \$ 3,860,000.	(+ 3,860,000)
P001 - 8 Nov 68 = 11,564,218	(+ 7,704,218)
P003 - 8 Apr 69 = 19,268,436.	(+ 7,704,218)
P005 - 19 Jun 69 = 24,359,501.	(+ 5,091,065)
P006 - 16 Jul 69 = 33,013,001.	(+ 8,653,500)
PZ07 - 31 Jul 69 = 57,146,841.	(+24,133,840)
P009 - 3 Dec 69 = 57,213,141.	(+ 66,300)
P010 - 3 Dec 69 = 58,200,141.	(+ 987,000)
P018 - 16 Jun 70 = 59,145,001.	(+ 944,860)
P019 - 1 Jul 70 = 83,485,386.	(+24,340,385)
P020 - 20 Jul 70 = 83,466,368.	(- 19,018)
P023 - 4 Sep 70 = 83,886,368.	(+ 420,000) <sup>3</sup>

Contract Totals (estimate as of 4 Sep 70)

Total Target Price (TTP)	\$79,611,691.
Over and Above Work	3,854,677.
Government Furnished Material (est)	2,200,000.
Spares	....239,020.
Total	\$85,905,388.

Note 1. Includes USCG obligation of \$1,200,000.

Note 2. Does not include any money for GFM or spares.

Note 3. The \$420,000. is a partial obligation pending definitization for the FY 71 buy. USAF obligation will include USN dollars; total planned on MIPR from USN is \$2,714,000.

categories which comprise the total contract price. Table 7B shows the cost data in the format it is presented in the AFLC Form 48 and is tracked in the D-17 Report, the cost-management report used by HQ USAF, HQ AFLC and WRAMA. Table 8B is a composite cost summary for the total USAF C-130 Center Wing Program less USAF in-house program management and certain engineering, test, inspection and repair costs. It is comprised of the best and latest estimates available on each item.

### Schedule

Just as costs may be viewed in many ways, so too may schedules. The only schedule considered here is the aircraft input-output. Engineering test program milestones, data and spares schedules are not included. Table 9B depicts input-output schedules by fiscal year and Military Service against time milestones. An aircraft is input when it arrives at Lockheed, output when the contractor's modification is accepted by the resident Government Inspector. Figure B2 discusses flow times in terms of calendar days, planned and achieved. Certain factors must be taken into consideration in analyzing this figure. The ordinate of Figure B2 can relate work days to calendar days at the ratio of 5/7; but in truth there may be more or less workdays per seven calendar days depending on holidays, weekends, or

Table 7B  
Cost Track - AFLC Form 48 and Budget Programs<sup>1</sup>

	CENTER WING MODIFICATION			RAINBOW FITTING		TOTAL <sup>2</sup>
	24 Apr 68 <sup>3</sup>	27 Aug 69	8 Apr 70	28 May 69	8 Apr 70	
A-(BP1100)	2,403.		13.	147.	3.	2,566.
B-(BP1100)	9.		8.	226.	2.	245.
D-(BP1100)	1.			6.		7.
E-(BP1100)	98.		8.		2.	108.
G-(BP1100)	42,712.		4,781.	1,662.	269.	49,424.
J-(BP1100)	1,755.					1,755.
Subtotal	46,976.		4,809.	2,041.	276.	54,105.
K-(BP16400)	43. <sup>4</sup>	402. <sup>4,7</sup>	55. <sup>5,9</sup>			500.
N-(BP431)	27,681. <sup>6,8</sup>	2,200. <sup>6</sup>	5,859. <sup>6,10</sup>	6,000. <sup>11</sup>	973. <sup>12</sup>	42,713.
Total <sup>2</sup>	74,700.	2.	10,723.	8,041.	1,249.	97,318

Note 1. Costs are in thousands of dollars; dates indicated AFLC Fm 48 approval by

CCB; ordinate codes are budget programs and items shown in Fm 48.

Note 2. Columns and rows do not total exactly because of rounding errors.

Note 3. These same dollar figures and BPs are quoted in MPD of 15 May 68.

Note 4. MPD/Amendment #1 of 15 May 70 placed these dollars under BP-1600.

Note 5. MPD/Amendment #1 of 15 May 70 placed these dollars under BP-4921-(6H).

Note 6. MPD/Amendment #1 of 15 May 70 placed these dollars under BP-4921-(6H).

Note 7. Broken out as BP-1600=\$179. and BP-4921=\$266.

Note 8. This figure includes \$4.0M for over and above work.

Note 9. Fund citation changed to or quoted as BP-4921 in Fm 48.

Note 10. Fund citation changed to or quoted as DMIF/P272710 in Fm 48.

Note 11. Fund citation changed to or quoted as DMIF/CUS P272710 in Fm 48.

Note 12. Fund citation changed to or quoted as DMIF P272710 in Fm 48.

**Table 8B**  
**Total USAF Cost for C-130 Center Wing Program**

<b>1. Inspection</b>		
USAF Inspection.....	\$ 1,000,000. <sup>1</sup>	
Contractor Inspections...	500,000. <sup>1,2</sup>	
	-----	
<b>Total</b>	<b>\$ 1,500,000.</b>	<b>\$ 1,500,000.</b>
<b>2. ECP Kits</b>		
Repairs.....	\$ 1,000,000. <sup>1</sup>	
ECP 939.....	2,279,336.	
ECP 912.....	4,750,752.	
ECP 941.....	1,000,000. <sup>1</sup>	
	-----	
<b>Total</b>	<b>\$ 9,030,088.</b>	<b>\$ 9,030,088.</b>
<b>3. Loads Measurement</b>		
Contract 68-C-1335.....	\$ 6,375,443.	
Contract 71-C-0070.....	1,596,295.	
Contract 68-C-1397.....	970,836.	
Contract 70-C-1825.....	747,438.	
	-----	
<b>Total</b>	<b>\$ 9,690,012.</b>	<b>\$ 9,690,012.</b>
<b>4. Modification</b>		
Contract 68-C-2530.....	\$ 97,315,593. <sup>3</sup>	
Aircraft downtime.....	9,890,000. <sup>4</sup>	
	-----	
<b>Total</b>	<b>\$107,205,593.</b>	<b>\$107,205,593.</b>
<b>5. Fatigue Test Program.....</b>		
	<b>\$ 3,162,179.<sup>5</sup></b>	<b>\$ 3,162,179.</b>
	-----	
<b>Total Program Cost.....</b>	<b>\$130,587,862.</b>	

- Note 1. Actual data for this effort could not be obtained, figure given is researcher's best guesstimate.
- Note 2. Lear Seigler Inc. and Lockheed Air Service provided field teams to accomplish this effort.
- Note 3. Figure is the total approved to date; estimates cost for 460 USAF aircraft.
- Note 4. Downtime calculated at \$500/day, the daily liquidated damages rate in WRAMA contracts (1968) using an average flow time of 43 calendar days. (460 x 500 x 43).
- Note 5. Fatigue Test Program is Contract 68-C-2956.



Table 9B  
C-130 Center Wing Aircraft Modification Schedule

Aircraft Input Output		28 Mar 68 Briefing	25 Apr 68 APP/DO	25 Apr 68 APP/DX	15 May 68 MPD	13 Jun 68 L/C	31 Jul 69 P207	3 Dec 69 P009	27 Feb 70 P013	16 Jun 70 P018	4 Sep 70 P023	Forecast	Actual
Fiscal Year 1969		82 67	0 0	52 37	52 37	37	53 30			53 30		53 30	53 30
Fiscal Year 1970		180 180	126 67	180 180	180 180	180	180 180			185		185 187	185 187
Fiscal Year 1971		138 153	180 180	168 180	168 180	180	179 181			174		190	
Fiscal Year 1972			94 153	0 3	0 3	3	0 21			0		88	
Input Service													
FY 69	USAF	82		52	52		53	53	53	53	53	53	53
FY 70	USAF	180	126	180	180		180	177	174	179	179	179	179
	USCG							3	6	6	6	6	6
FY 71	USAF	138	180	168	168		179	179	179	174	157	167	
	USCG											6	
	USN										17	17	
FY 72	USAF		94									61	
	USCG											4	
	USN											23	
TOTAL		400	400	400	400	400	412	412	412	412	412	516	

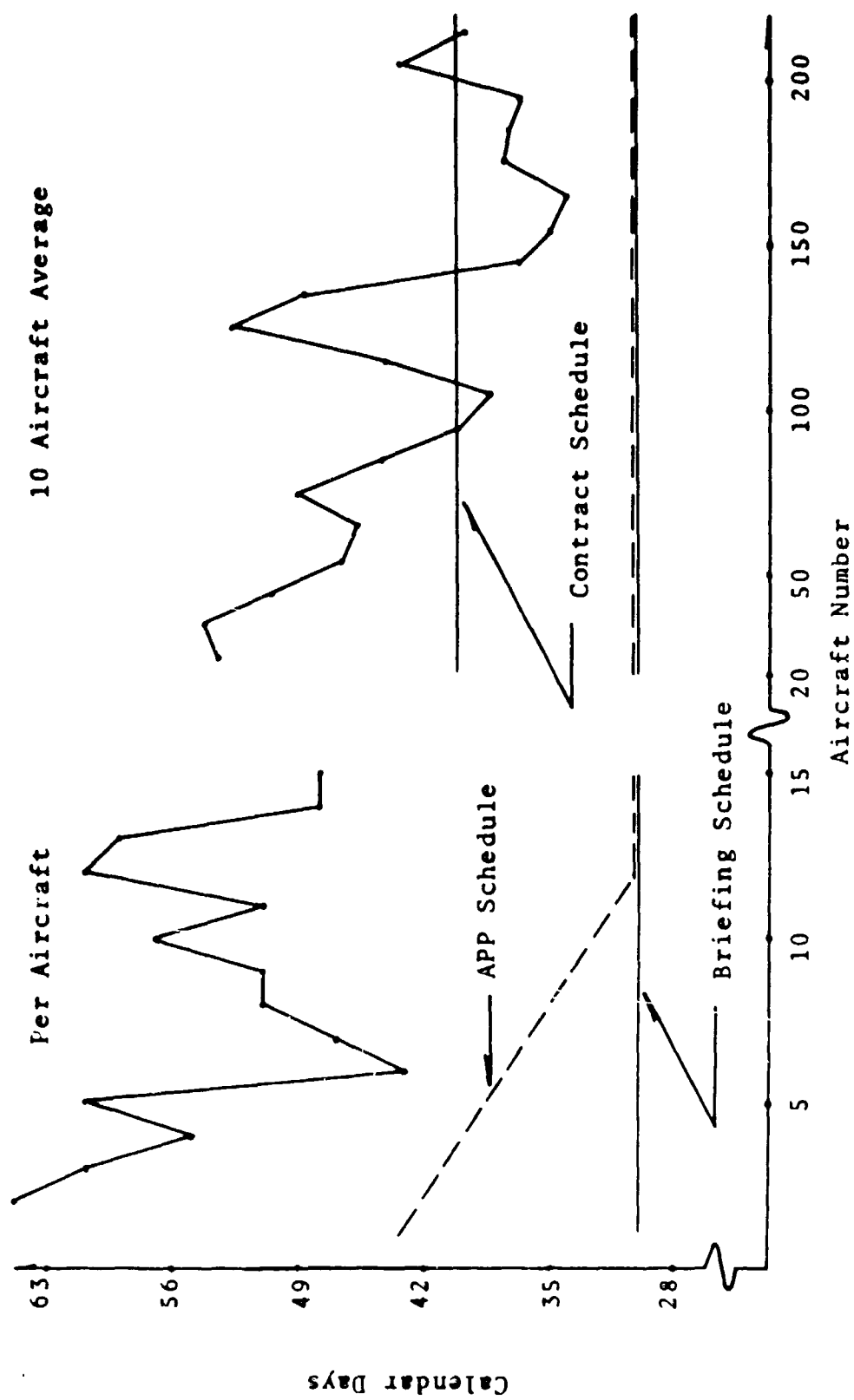


Figure B2. Aircraft Flowtime.

if overtime is worked. Also the contract makes provisions for aircraft deliveries, i.e., outputs, to slip because of inclement weather for flight test, non-availability of USAF flight test crews, required engine or propeller changes, additional unexpected over and above work, or late aircraft input. One or any combination of these events could contribute, and be acceptable, to a delivery slipping a planned schedule date.

#### Performance

Performance in the usual context refers to those parameters such as speed, weight, thrust, or MTBF. The parameters are usually specified directly or in combinations in the contract specifications. Performance, as such, is not as critical or as detailed in this modification, versus designing and developing a new weapon system.

In this chronology the term performance relates to all the design objectives, particularly the 10,000 flight hour objective, plus the quality of manufacture and reliability. Performance is not associated with the contractor's ability to meet costs or schedules. To this end, all records and data reviewed and personnel interviewed indicated the contractor has, and is achieving the performance requirements.

### Commentary

The case history of the total C-130 Center Wing Program was pieced together from numerous records and interviews at HQ AFLC and WRAMA. This situation was in part due to the functional organization structure of AFLC procurement. Because of personal resource limitations, certain aspects of this modification program could not be thoroughly investigated and research. This subsection relates some of the observations and reflections of the researcher; some that could not be explicitly substantiated or corroborated.

Accurate cost tracks were extremely difficult to come by. Each organizational level concerned itself only with that portion of the program for which it was responsible. Financial management reports were not easily correlated. Contractor financial reporting was by contract line item and appropriation codes, while AFLC tracked by appropriation, AFLC Form 48 and D-17 Reports. Financial personnel have their own lexicon. Changes in appropriation and Budget Program codes and in accounting techniques, such as switching to Stock and Industrial Funds in recent years, further complicated the research. Performance data was similarly limited.

The personnel who aided in providing data for this research were extremely sincere, conscientious and hard-working. The pressures of short deadlines and budget

constraints are more real to them than cost growth. It appeared that pressures to avoid cost increases, stay within approved dollar levels, and incremental funding problems affected program decisions more than any other single factor. This may have been the root cause for delay in awarding Contract 68-C-2530, deleting the landing gear modification and warranty clause, and switching aircraft outputs between fiscal years. Desire for program approval and initial funding may have been at the base of omitting from the initial briefing, recognition of the total complement of USAF C-130B/E aircraft in the inventory, need for modifying the HC-130H/P aircraft and replacement of the outer wing rainbow fittings, and inclusion of GFM costs. Answers and data to investigate these considerations could not be obtained.

Resource limitations also prevented examination of this program using contractor records and personnel, a vital ingredient in any study of cost outcomes. Lacking such documentation this commentary is offered. By early 1968 Lockheed had completed its production run of 284 C-141 aircraft and C-130 sales were down. The C-5A program, awarded to Lockheed in October 1965, was experiencing serious financial and technical problems. The award of a 400 aircraft modification program, with growth potential to over 515 aircraft, could provide needed funds and help stabilize the labor force as the C-141 program

wound down and the C-5A production increased. The degree to which this atmosphere influenced the initial proposal is unknown. Optimism in cost and schedule appears to have pervaded. The C-5A financial and technical problems continued into 1970. The C-5A program became a political football. The degree to which these events affected the C-130 costs, schedules and performance is also an unknown quantity. It is impossible to believe they were mutually independent events.

Footnotes for Appendix B

1. WRAMA(MM) Historical Summary-FY 68, C-130 Hercules Center Wing Fatigue.
2. Ibid.
3. Ibid.
4. HQ AFLC (MCMTA) C-130 File, "Chronology of Briefing by LGC," undated.
5. WRAMA(MM) Historical Summary-FY 68, op. cit.
6. Ibid.
7. Ibid.
8. Ibid.
9. Ibid.
10. Ibid.
11. WRPWCA Msg 14 2021 Feb 68.
12. WRP Msg 17 1421 Jan 68.
13. Official Contract Files, WRAMA(PPCA).
14. MCG Msg 08 1700 Dec 67.
15. MCG Msg 20 2225 Dec 67.
16. WRAMA Briefing, C-130 Center Wing Problem, 28 Mar 68.
17. AFSDC Msg 10 2246 Apr 68.
18. Letter-Contract F09603-68-C-2530, 13 Jun 68.
19. Advance Procurement Plan, undated.
20. CSAF Msg 26 1927 Apr 68.
21. Modification Program Directive No 10009, 15 May 68.
22. WRG Msg 20 1800 May 68.
23. Letter Contract, op. cit.

24. WRAMA(WRP) Narration of Procurement Action, Definitization of Letter Contract F09603-68-C-2530.
25. AFLC Fm 48, Installation of Improved Outer Wing Rainbow Fitting, C-130B/E Acft, 9 May 69.
26. MCMT Msg 20 Mar 69.
27. WRNEAS letter dated 5 Apr 68, subject: Lockheed-Georgia Co. ETP 782.
28. MCMT Msg 26 Mar 69.
29. MCM Msg 26 2150 Feb 69.
30. WRG Msg 14 1328 Mar 69.
31. MCM Msg 24 2147 Apr 69.
32. AFLC Fm 48, op. cit.
33. Atch #1 to AFLC Fm 48, 12 Feb 69.
34. MCM Msg 26 2150 Feb 69.
35. WRG Msg 10 2231 Mar 69.
36. Letter Contract, op. cit.
37. Official Contract File, F09603-68-C-2530, WRAMA(PPCA).
38. AFLC Fm 48, Modification for Improvement of Center Wing Fatigue Endurance of HC-130H/P Series Acft, 24 Mar 70.
39. AFLC Fm 48, Installation of Improved Outer Wing Rainbow Fittings HC-130H/P Acft, undated; approved by AFLC CCB 8 Apr 70.
40. AFLC Fm 48, Modification for Improvement of Center Wing, op. cit.
41. MPD Amendment #1 to Class IV Mod No 10009, 15 May 70.
42. Contract File, WRAMA(MMEOO).



APPENDIX C

B-52 STABILITY AUGMENTATION SYSTEM PROGRAM

## APPENDIX C

## B-52 STABILITY AUGMENTATION SYSTEM PROGRAM

This appendix presents a chronological accounting of the B-52 Stability Augmentation System Program. The program to incorporate an improved stability augmentation system in B-52 G and H model aircraft stemmed from special life studies on the B-52 aircraft. In particular, it grew from studies aimed at improving the airplane's structural life and its aerodynamic and structural stability in severe turbulence. There is one HQ USAF directed Class IV modification, No. 10007, in this program. This modification directs the fabrication and installation of an improved stability augmentation system into all B-52G/H aircraft. The system achieves the objectives by providing the aircraft with an improved lateral-directional stability which reduces structural loads and improves controllability in turbulence.

The improved system was designed and prototyped by The Boeing Company, Wichita Division. The production modification kits were initially procured from Boeing under contract from the Oklahoma City Air Materiel Area; later directly from the manufacturers of the kit components and Boeing. The kits are installed on the Strategic Air Command aircraft at the Oklahoma City and San

Antonio Air Materiel Areas during scheduled maintenance or special fly-in programs.

A summary of the program is given in Figure C1. The program spans eleven years and depicts the program as it had occurred and was envisioned as of October 1970. The special studies, kit prototyping, fabrication, delivery and installation, and the procurement actions involved in the program and Mod No 10007 are the subject of the subsequent sections.

#### Background

The B-52 airplane is a subsonic, high altitude bomber designed and developed for the United States Air Force by The Boeing Company. Aircraft production began in February 1951 and the first production model was delivered to the Strategic Air Command (SAC) in June 1955. A total of 742 aircraft were manufactured in eight models before production ended in October 1961. There are currently 517 aircraft in the active USAF inventory; 500 of which are in SAC. To provide increased range over the earlier models the B-52 G and H had integral fuel tanks added to the wings; also, the airframe was partially redesigned. Both models are capable of carrying bombs and the air-to-surface missiles Hound Dog and Quail. The B-52G is powered by eight turbojet engines while the B-52H has eight turbofan engines to increase its range

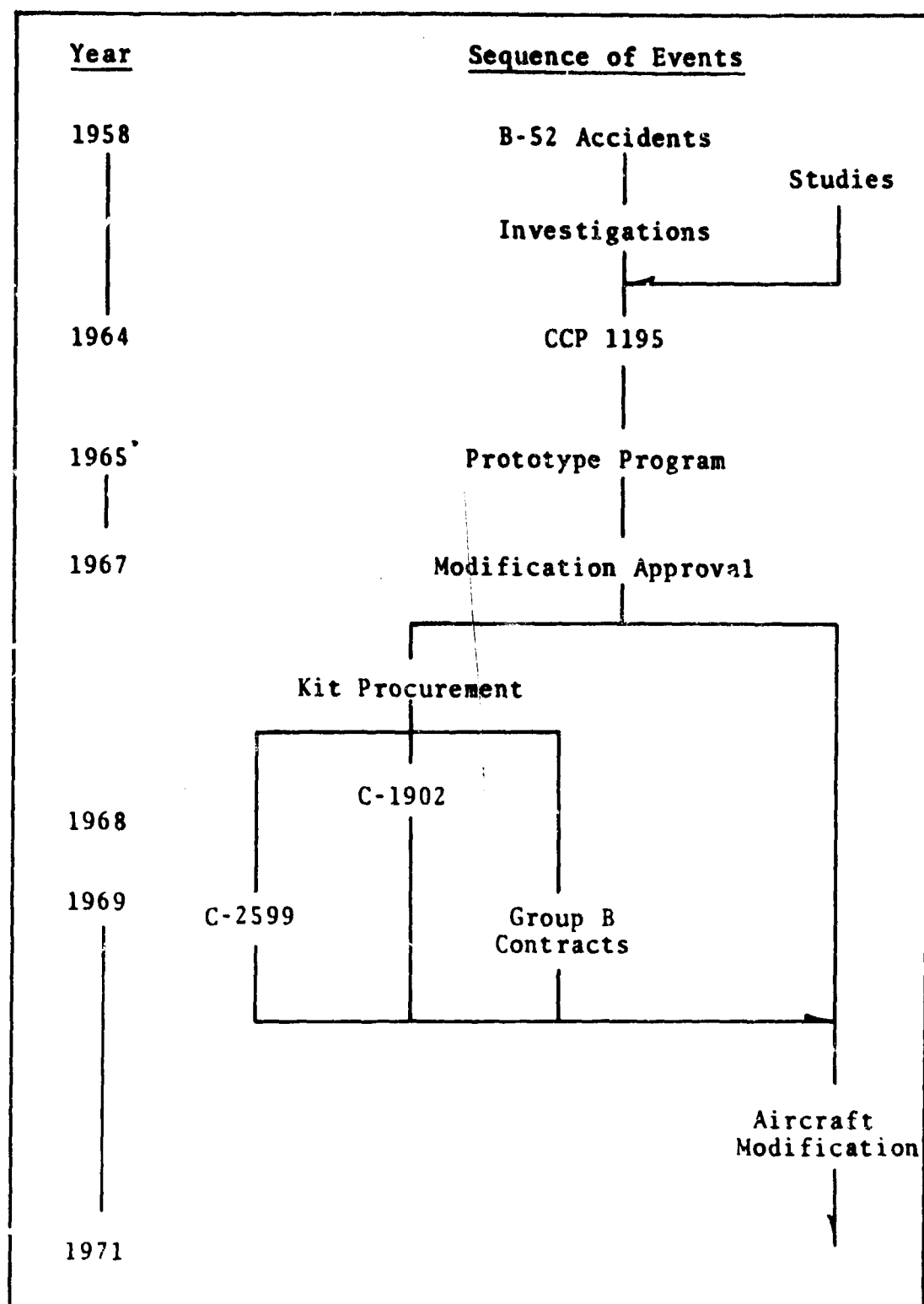


Figure C1. B-52 Stability Augmentation System Program Summary.

to 12,500 miles. The System Support management functions for the B-52 are the responsibility of the Oklahoma City Air Materiel Area (OCAMA), Tinker AFB, Oklahoma.

### Life Studies

The history of Modification 10007 had its origin in the time period of 1958 to 1964. During this period ten major B-52 accidents occurred that were related to turbulence or controllability. Investigations and special study committees, most notably the Ashley Committee (1963) and the Davis-Montgomery Committee (1964), resulted in major structural modifications and additional studies being performed on the B-52 fleet.

The Office of the Secretary of Defense (OSD) report prepared by Mr. James Davis and Dr. Richard Montgomery completely changed the ground rules for future life sustaining modifications. Their report specified two new requirements which relate to this history. First, there would be an operational requirement for B-52 aircraft through 1975; second, that the feasibility of an improved stability augmentation, as a means of reducing maneuver loads and the accrual of fatigue damage, be determined.<sup>1</sup> Based on this report and HQ USAF direction, studies were conducted by The Boeing Company, hereafter referred to as Boeing, and the Oklahoma City Air Materiel Area (OCAMA). The B-52 Stability

Augmentation Study (CCP 1195) was conducted to determine the adequacy of the present stability devices and the requirements for changes in the stability augmentation and flight control system that would provide meaningful improvement to the airplane's structural life and its aerodynamic and structural stability in severe turbulence. Specifically, the study objectives were to study the stability augmentation system (SAS) in order to improve fatigue life, reduce peak loads and improve handling qualities.<sup>2</sup> It was recognized by this time that because of development lead time, any recommended improvements would be limited to the B-52G/H fleet.<sup>3</sup> In late 1964 a Boeing cost estimate of \$32.2 million was stated to modify the B-52G/H fleet (291 aircraft).<sup>4</sup> This estimate was taken from very preliminary data, but did break out costs for kits, test, tools, spares, AGE and labor. However, this estimate was based on modifications that were not completely defined, nor concurred in by OCAMA. The CCP 1195 Study was completed in July 1965.

#### Prototype Program

Following completion of the CCP 1195 Study a prototype program was initiated. The CCP 1195 Prototype Program consisted of two contracts, AF34(601)-25146 and AF34(601)-27372. It provided for the analysis, design, fabrication and flight testing of a prototype pitch and

yaw improved flight control system and a stability augmentation system (SAS) that improves the Dutch roll damping, reduces the structural loads and improves the controllability in turbulence for the B-52G/H aircraft.

Production component specifications were to be prepared also.<sup>5</sup> The prototype and flight test program was completed in August 1967. The prototype system as developed and tested can be described as follows: Integrated, force limited, hydraulic actuators are installed to power the rudder and elevator control surfaces in response to pilot input, SAS or autopilot inputs. Two completely independent hydraulic systems are added to provide hydraulic power for the new actuators. Each system has a backup power source through hydraulic transformers to two of the existing hydraulic systems. New SAS electronics components consisting of triply redundant sensors and control units for the yaw and pitch axis systems were developed and are installed. The redundant circuits are monitored by logic networks to vote out a first failure in the system and turn off the system after a second like failure. Structural changes were incorporated in the vertical and horizontal surfaces to accommodate the new hydraulic actuators.<sup>6</sup> The total cost of the feasibility study, prototype and flight test was \$12 million.<sup>7</sup> Frequently, \$9,634,218. of this figure appears in financial data associated with Mod No 10007.

However, to be correct and consistent, the \$9.6M is associated with development and the total program, but is not an integral part of Mod No 10007. The \$9.6M when broken out by fiscal year is: FY 66 - \$6,921,947. and FY 67 - \$2,712,271.; it is referred to as Prototype Engineering and was financed by BP 1100 funds.

#### Modification Program

This section is in four parts. The first relates the background and details of program approval and go-ahead. The next two parts discuss kit procurement. The procurement of the 284 production modification kits was in two increments. In the first increment, sometimes referred to as Phase One, 125 complete kits were purchased directly from Boeing. In Phase Two, the components for the remaining 159 kits were purchased directly by OCAMA from the component part manufacturers and Boeing. Each phase is discussed as a separate subsection. The fourth part of this section discusses modification program costs and aircraft schedules.

#### Program Approval

The results of the Prototype Program were presented in briefing form to HQ SAC on 5-6 September, HQ AFLC on 7 September and HQ USAF on 8 September 1967. It was recommended that Boeing ECP 1195K be installed on all



B-52G/H aircraft;<sup>8</sup> program cost, schedule and performance figures were presented.

Boeing had submitted a budget proposal to OCAMA for ECP 1195K in June 1967. As a result of the presentation made at HQ USAF in September, Boeing revised this proposal. The prices and quotes provided in this revision of 15 September 1967 were based on receipt of authorization for program go-ahead on or before 1 November 1967.<sup>9</sup> The total estimated price was \$51,110,097. Boeing quoted "for budget purposes only, an estimated contract sales price" for 288 kits of \$42,164,352. (unit price = \$146,404), which consisted on Engineering = \$3,287,070., Labor = \$7,332,472., and Materials = \$31,544,790. The difference of \$8,945,745 was for five sets of installation tooling (\$0.8M), spares (\$3.00M), data (\$0.88M), AGE (\$3.35M), trainer change proposal (\$0.85M), and for technical support personnel services for kit proofing, additional facilities and training (\$0.06M).<sup>10</sup> Kits were to be delivered at the rate of 10 in April 1969, and 20 per month thereafter, completing kit delivery by 30 June 1970. A separate schedule was provided for the installation tools. This schedule was predicated on Boeing receiving a waiver to a Technical Order (TO), thereby permitting Boeing to build and ship the ECP 1195K airplane kits prior to or concurrent with kit proofing.<sup>11</sup> Two aircraft modification

schedules were provided in the proposal. The SAS kit installation could be completed approximately one calendar year earlier if a Boeing and depot team installation program was approved versus a depot only installation. Under the joint venture all aircraft could be retrofit by 31 March 1971 at a labor cost of \$8.9M. If this concept were approved, the total cost for incorporation of the improved SAS in the B-52G/H fleet would be \$60.1M: \$51.2M for kits and support equipment and \$8.9M for labor.<sup>12</sup> Two notes should be made at this point. One, Boeing's proposal was for 288 kits; no estimates were provided for smaller quantity buys. Two, the kit quantity required decreases throughout this history because of aircraft attrition.

ECP 1195 was approved as a HQ USAF directed Class IV modification on 4 October 1967 when the Modification Program Directive (MPD), "B-52 G&H ECP 1195," was issued. Later, this MPD was assigned Mod No 10007. It directed that the prototype system, described earlier, be installed on all B-52 G and H aircraft, which at that time was 288. The SAS retrofit kit schedule required was that presented to the Air Staff (HQ USAF) on 8 September 1967. The first aircraft input was to be not later than April 1969 and the last input not later than June 1971. The total estimated cost for fleet incorporation was \$60.1M. The breakout of estimated costs by fiscal year

and Budget Program is shown in Table 1C. A 2000 hour mean time between failure (MTBF) for the stability augmentation system was established. The MPD made appropriate provisions and note of the requirements for modifications to Mobile Training Units (MTUs) and Simulators, personnel training, AGE and test equipment, spares and revisions to Technical Manuals.<sup>13</sup>

Table 1C  
Initial Modification Program Directive Cost Breakout<sup>1</sup>

	FY 68	FY 69	FY 70	FY 71	Total
BP 1100	\$26.1	21.6			\$47.7
BP 1600	2.1	1.4			3.5
P 431		.9	4.7	3.3	8.9
Total	\$28.2	23.9	4.7	3.3	60.1

Note 1. Costs in millions of dollars.

Source: MPD, 4 Oct 67.

(Researcher's Note. The kit delivery schedule required by the MPD was the same promised by Boeing in its 15 Sep 67 proposal, but no mention was made in the MPD about the waiver required to the TO, nor the need for program authorization by 1 November 1967. In a similar

vein, the aircraft input schedule and labor costs (P431) were the same as proposed by Boeing, but without any reference to a joint effort.)

#### Phase One

Procurement planning for purchase of the ECP 1195 kits commenced at OCAMA in April 1967. The Directorate of Procurement and Production (PP) had suggested to the Directorate of Materiel Management (MM) the need for advanced planning and the possibility of sizeable dollar savings if OCAMA procured certain kit items directly from the manufacturers rather than as subcontracted items to Boeing. But, the position of MM was to buy at least the initial increment of kits (125) including vendor items from Boeing. A Purchase Request (PR) to this effect was sent from MM to PP in November 1967.<sup>14</sup> The PR provided funds in the amount of \$25.3M, and by April 1968 authorization was available to expend \$26.1M in FY 68 BP 1100 funds.

Although Boeing had not furnished a budget proposal to OCAMA for 125 kits, it did indicate that for funding purposes \$26.1M should buy 125 kits and the necessary spares, AGE, training, data, etc.<sup>15</sup> However, this figure included the average price for 289 kits times 125, but did not recognize non-recurring costs and start-up costs amortized over fewer units.<sup>16</sup> Note

that the FY 68 Program Funding estimate in the 8 Sep 67 briefing was \$26.1M and \$28.2M in the MPD, vis., BP 1100 = \$26.1M and BP 1600 = \$2.1M.

Letter Contract F34601-68-C-1902 was issued by OCAMA on 29 December 1967 to The Boeing Company, Wichita Division, Wichita, Kansas. The letter contract obligated \$10,076,793 for the procurement of 125 Class IV modification kits together with related spares, AGE, data, and tooling in accordance with ECP 1195K. A Fixed Price Incentive, Successive Targets with Value Engineering (FPIS-V) type definitive contract, in the estimated amount of \$25,318,000 was contemplated.<sup>17</sup> This type contract was planned since Boeing had advised OCAMA in early November 1967 that a proposal based upon firm engineering could not be submitted for 200 days after contract go-ahead. Award of the letter contract was delayed by OCAMA attempts to incorporate warranty provisions into the contract as requested by the MPD, but with no success. Issuance of the letter contract was finally made to prevent further slippage;<sup>18</sup> first kit availability was already predicted to slide from April 1969 to June 1969.<sup>19</sup>

On 15 April 1968 Boeing submitted a firm price proposal of \$42.2M to OCAMA for the letter contract requirements. This figure, although a proposal, was \$16.9M more than the funds available, and \$16.1M more than

Boeing had indicated in late 1967. The \$42.2M price proposal can be examined from two points of view. One, the figure is comprised of \$34.2M for 125 kits, including kit proofing, test equipment, kit data, TCPs, and kits to modify spares, plus \$8.0M as a planning figure to cover the price of installation tools, spares provisions, AGE provisions, manuals, and CFAE/CFE publications. Or two, the figure is comprised of the \$26.1M as estimated in late 1967, plus \$3.3M for non-recurring costs and start-up costs not previously recognized, plus an \$8.2M increase in the cost of the Bendix system (Bendix was a Boeing subcontractor), plus \$2.7M in other vendor and miscellaneous material prices, plus \$0.4M for Boeing in-house price increases and \$1.5M extra for spares and AGE primarily associated with the electronics portion of the system.<sup>20</sup> One million dollars of the above \$2.7M figure was from another subcontractor, Weston. Weston and Bendix attributed the increases to understating budget proposals and underestimating the requirements necessary to convert a prototype system to production hardware.<sup>21</sup> Other factors contributing to the increase were changes in the work package, better definition of the kit work statement and the partial release of engineering, and an increase in the elements of the original basis unit price.<sup>22</sup>

For the next two months the program was reviewed and alternatives evaluated before final program redirection was approved by HQ USAF. Following proposal evaluation by OCAMA, management meetings were held with Boeing in May 1968. Boeing and the applicable vendors had been requested to discuss and defend the cost increase and to present alternatives that would allow the modification to stay within funds allotted and still accomplish, if possible, the modification intent. OCAMA directed expenditures and obligations be minimized without impacting funds and/or kit schedule until the problem could be resolved.<sup>23</sup> The major thrust of the effort was to roll back the price to within the original estimate of \$51.2M for the total hardware buy,<sup>24</sup> i.e., reference Table 1C: total of BP 1100 and BP 1600 funds for all fiscal years equals \$51.2M.

Two alternatives were deemed feasible. One alternative reduced the number of black boxes in the yaw axis electronics at a proposed savings of \$6.3M, and the second removed the electronics from the pitch system and revised the elevator actuators for a proposed savings of \$9.4M. If both alternatives were adopted the possible cost reduction could be \$15.7M.<sup>25</sup> The alternative to reduce the number of black boxes per airplane from eleven to six in the yaw axis electronics was referred to as

reorganizing or repackaging the black boxes<sup>26</sup> and called Configuration #1. Configuration #2 was the program revision of both alternatives, i.e., reorganizing the yaw electronics, deleting the pitch electronics and revising the elevator actuators. Configuration #1 was to have no effect on performance, safety or reliability, and slightly degrade maintainability, while Configuration #2 would slightly degrade the first two categories and slightly improve the latter two.

On 27 May 1968 OCAMA recommended to HQ AFLC acceptance of Configuration #2. Approval of HQ USAF was necessary since a waiver to the MPD would be required to delete the pitch electronics. Boeing had already been directed by OCAMA to proceed with reorganizing the yaw electronics. Acceptance of this recommendation coupled with buying the remaining 161 aircraft kits directly from the vendors was supposed to offset the price increase of \$16.1M on the first kit buy and reduce the entire kit and support equipment cost from \$51.2M to \$48.8M;<sup>27</sup> if only Configuration #1 and the vendor buy was approved, the cost would be \$57.6M. On 7 June 1968 HQ USAF concurred in the OCAMA position to reorganize the yaw electronics and go direct to the vendors for the remaining kits, but did not approve deletion of pitch electronics. This decision was based on input from SAC regarding reduction in fatigue damage, the possibility of structural



overloads and mission considerations. Modest price increases were anticipated and to be justified by AFLC.<sup>28</sup> Based on this direction, OCAMA requested Boeing to submit an updated price proposal based on Configuration #1 by July 1968. On 24 June 1968 HQ AFLC requested that USAF increase the total BP 1100 and BP 1600 funds to \$56.32M for FY 68 and FY 69, an increase of \$5.12M from the MPD.<sup>29</sup>

(Researcher's Note. The above data is strongly correlated to that furnished by Boeing during a program review in May 1968.<sup>30</sup> Other pertinent data from this review are: (1) The cost data uses a 286 aircraft base versus the MPD of 288, and (2) The cost savings of \$6.3M and \$15.7M are planning estimates for kits based on a two-buy concept and do not include the program net cost increase/decrease if initial lay-in items and five year operational costs are considered for each configuration.)

Following contract negotiations held in July 1968, the letter contract, F34601-68-C-1902, was definitized by Contract Modification P007 effective 29 July 1968. The contract was a FPIS-V type with an initial target cost of \$26,300,000., an initial target profit of \$2,038,250., an initial target price of \$28,338,250. and a ceiling price of \$33,532,500. The negotiated initial price of \$28.3M represented a reduction of \$1.9M from the revised Boeing proposal of 1 July 1968. Note, these

figures do not include installation tools, nor spares and AGE provisions and the \$28.3M is comparable to the \$34.2M stated in the Boeing proposal of 15 April 1968 rather than the \$42.2M.<sup>31</sup> The contract specified kit delivery schedules in accordance with Table 2C. In addition, schedules were specified for other line items of the contract, e.g., Item 2: 174 kits to modify spares were to be delivered by May 1969; Item 3: kit proofing was to be accomplished by August 1969; Item 6: Four MTUs were to be delivered, one in May, September, November and December 1969.

As of October 1970 fifty-nine Change Orders had been processed on this contract, the majority for minor changes under \$100,000 or for administrative purposes. Two major changes that did occur were P052, 26 May 70, which obligated \$106,203 and which remains to be definitized, and P042, 19 Aug 69, for \$286,000. Both Change Orders increased contract obligations to permit modification of the ECP 1195 kit in accordance with engineering revisions. These changes will be discussed in more detail later.

Negotiations were held in May and June 1969 for the purpose of establishing the firm target amounts for Contract C-1902, as well as for definitizing outstanding Change Orders. These negotiations resulted in a target cost of \$25,372,439., a target profit of \$2,036,497., a target price of \$27,408,936. and a ceiling price of

Table 2C  
ECP 1195 Kit Deliveries

	1969										1970					
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
Proposal <sup>1</sup>	10	20	20	20	20	20	20	20	20	20	20	20	20	20	18	
C-1902			8	12	12	10	14	14	14	14	14	14	13			

Note 1. Boeing Proposal dated 15 Sep 67.

\$33,503,660 with a 75/25 sharing arrangement. A unit cost per kit of \$211,814 was negotiated. As of October 1970 the total amount obligated on this contract was \$27,912,962., and although there are outstanding orders the total price will probably not exceed \$29M.<sup>32</sup>

This subsection will end with a brief description of some problems encountered in Phase One. One must not be misled to believe that Phase One and Phase Two are in series. The truth of the matter is that they are more in parallel. Phase One formally began in December 1967 with Contract C-1902 and was still active when this research was conducted; Phase Two formally began with contracts awarded in early 1969. Reference Figure C1. Phase Two will be discussed in more detail in the next section. The point to be made is that because of the near parallel arrangement of the phases, problems of a technical, schedule or cost nature which occurred in one phase were not mutually exclusive of problems in the other.

As noted above, engineering revisions to the ECP 1195 kits were required to correct deficiencies or improve its operation. Item 18 of Contract C-1902 summarizes the cumulative total cost for all these revisions. As of P055, 21 July 1970, the total price was \$333,080. Probably the most significant of the revisions dealt with kit changes ECP 1195R7 and 1195R8 to

correct electromagnetic interference (EMI) problems. Reference the earlier discussion of P042. EMI problems occurred between the SAS and the AN/ARC-58 HF radio on three separate occasions in the program: formal flight test, kit proofing, and in ground test. Although each problem was different, each involved EMI which resulted in SAS elevator and/or rudder deflections during HF radio transmission or by ARC-58 FR energy being conducted into the airplane power circuits by a ground power cart cable. Revisions R7 and R8 corrected this incompatibility.<sup>33</sup> However, this problem in conjunction with a hydraulic actuator forging problem, forgings being unacceptable due to oscillation of the rudder actuators during flight, contributed to Boeing being unable to deliver any kits in June 1969.<sup>34</sup>

Some of the development and production problems affected the support posture of the program. Two of the more significant were electronic hardware unreliability and late delivery of field test equipment. Heavy infant mortality caused by design and quality deficiencies was experienced on installed electronic equipment; a 50 hour burn-in test had to be initiated in October 1969. Production problems and design changes to hardware resulted in field test equipment deliveries slipping schedule.<sup>35</sup> Revised aircraft delivery schedules and the limiting of the dispersal of modified

aircraft were necessary to overcome these problems in the latter half of 1969.

A meaningful, actual kit delivery schedule for Phase One is difficult to generate. Table 2C listed the proposed and contractually required basic kit delivery schedule. Note that some kit revisions were on separate delivery schedules, e.g., R8 kits were shipped separate from the basic kit. All kit components were not required for kit installation for up to 26 days after the aircraft was input to the depot. Therefore, for a variety of reasons, particularly vendor problems with the electronics and actuators, kits were shipped short from Boeing, i.e., less certain components. These components were shipped later to support aircraft schedules. Information available at OCAMA indicated that the kits were made available in time to support aircraft schedules.

#### Phase Two

This phase discusses the second increment of kit procurement, the purchase of the remaining 159 modification kits. This phase can be subdivided into two parts: one, the follow-on contract to Boeing for the purchase of Group A components for 159 kits and ancillary equipment; and two, the purchase of 14 Group B components by OCAMA direct from six suppliers on seven contracts.

Letter Contract F34601-69-C-2599, effective 3 February 1969, was issued as a follow-on contract to C-1902 to purchase Group A components for 100 modification kits in accordance with ECP 1195K. Kit deliveries were to start in March 1970. The total price estimated by OCAMA(MM) was \$3,085,301. The contract was for 80 kits, but contained an option for the remaining quantity of kits. This option was included since HQ AFLC was of the opinion current funds available were insufficient to accomplish the complete buy. Change Order P001, 15 July 1969, exercised the option for the remaining 79 kits.<sup>36</sup> Note, because of aircraft attrition only 79 kits were then required in lieu of the planned option of 80. A deficiency in kit funding had occurred in early 1969. In order to put the 80 kits on contract, \$590,000 of the \$977,000 approved for kit proof testing (engineering) was used to procure the kits. Additional funds were required in late April 1969 to prevent slippage in kit proof testing and delivery of production modification kits.<sup>37</sup>

Based on negotiations held in July 1969 between Boeing and OCAMA, Contract C-2599 was definitized as a Fixed Price Incentive Firm (FPIF) type by Change Order PZ02, 5 September 1969. The contract target cost was \$3,575,433., target profit at 9% was \$321,790., thus target price was \$3,897,223. An 80/20 sharing arrangement

and an 118% ceiling price were also negotiated. The definitized contract purchased 159 kits in accordance with ECP 1195K, R1 and R4, 59 kits to modify spares, 1 Mobile Training Unit (MTU), 284 AGE modification kits, 114 AGE spare parts, engineering services and data. The modification kits were to be delivered starting with one (1) in March 1970 and fourteen (14) per month thereafter, completing the buy with four (4) in March 1971. Separate delivery schedules were negotiated for the spares, AGE, MTU, and data.<sup>38</sup> As discussed earlier, problems which occurred with the Phase One procurement affected Phase Two, e.g., the EMI problem was at its zenith while this contract was in negotiation.

The Group B components for the second increment of modification kits were purchased by OCAMA direct from each of the equipment suppliers and were shipped directly to a Materiel Utilization Control Office (MUCO) at the AMA. When required, these components would be drawn from the MUCO and combined with the Group A components supplied by Boeing to assemble a complete kit for installation by USAF personnel at the AMA, i.e., either SAAMA or OCAMA.

Because of the functional nature of the organizational structure of the AMA, program management of the Group B components was the responsibility of two different organizations. Group B components of an accessory



nature, such as motors, pumps, actuators and transformers, fell under the purview of the Accessories Inventory Manager (IM) while electronics, sensors and similar items were the responsibility of the Instrument System IM.

The Inventory Managers (IMs) like the System Support Managers (SSMs) are under the Directorate of Materiel Management (MM) at an AMA. Thus, the IMs for the Group B components and the B-52 SSM had to maintain liaison and coordination to integrate total program management. In turn, the procurement of the accessories and instruments at OCAMA, that is, the award and administration of contractual matters, are handled by buyers in different sections of the Accessories or the Instrument Branches of the Commodities Procurement Division, a different Division than the Weapon System Procurement Division, B-52 Branch, responsible for Contracts C-1902 and C-2599.

The Instrument System IM has managerial responsibility on ECP 1195 for five high value items: rate sensor units (RSU), accelerometer units (AU), parameter scheduling units (PSU), yaw electronics control units (YECO), pitch electronic control units (PECO); three insurance type mounts; modules and stock items; and maintenance and overhaul (M&O) parts estimated in number at 2500.<sup>39</sup> The five high value items and the three mounts constituted eight of the fourteen Group B components; the remaining six are termed accessories and are discussed in a subsequent paragraph. To purchase these

items a Fixed Price (FP) type contract was awarded by OCAMA to the Bendix Corporation, Navigation and Control Division, Teterboro, N.J. The contract, F34601-69-C-2685, effective 7 July 1969, required Bendix to furnish 322 RSU and 161 each AU, PMU, YECO and PECO; bases, investment and expense spares and data at a total price of \$7,591,000. These items were to be delivered according to contract schedules from January 1970 through November 1970.<sup>40</sup> Bendix was a subcontractor to Boeing on Contract C-1902 and these units were to be identical to those furnished on that contract.

(Researcher's Note. This contract is typical of many which include a requirement for spare parts. Often the description and quantity of the spares required are not available when the contract is awarded. So a contract line item is established, a token amount of money is allotted to reserve this line item and interim release procedures apply. Once the spares provisioning document is available, the Provisioning Contracting Officer will issue a written Spare Parts Order. These parts will be identified in a priced spare parts exhibit and additional dollars released. On this contract, only \$2,000 was allocated initially to establish Contract Line Item 2 with two subitems: 2AA - Investment Spare Parts and 2AB - Expense Spare Parts. Spare parts once identified would appear in Exhibit J to Contract

C-2685. Therefore, although an initial contract price may be described as including the price of spare parts, often it is only a token amount which will be increased at a later date.)

In the latter half of 1969 design and quality deficiencies in the units Bendix supplied to Boeing under Contract C-1902 caused a heavy infant mortality rate, and a burn-in test had to be initiated. Also, starting in October 1969 a joint Bendix/Boeing Reliability Committee was formed and Bendix engineers were provided to each of the B-52 modification centers (OCAMA and SAAMA) to accomplish as much repair as possible 'on site.' Bendix delivery schedules slipped three months. As a result schedules on Contract C-2685 were subject to a similar slippage. In December 1969 agreement was reached between Bendix and OCAMA to slip schedules on Contract C-2685 from January to April 1970; in consideration Bendix would do a burn-in test on all units shipped prior to 1 May 1970.<sup>41</sup> This agreement was formalized along with increased quantity requirements by Change Order P003, 5 March 1970. Forty-six RSU, 17 AU, 39 YECO, 23 PECO and 32 PSU were added to the contract. These changes increased the total contract price to \$8,916,057. P001 and P002 were minor administrative changes.

Table 3C summarizes the Group B components for which the Accessories IM has responsibility. This

Table 3C  
Group B Components - Accessories

Quantity	Nomenclature	Supplier	Contract
322	Elevator Actuator	Weston Hydraulics Van Nuys, CA	F34601-69-C-4073
166	Rudder Actuator	" "	" "
320	Reservoir	New York Airbrake Watertown, NY	F34601-69-A-2241
320	Motor-Pump Assy <sup>1</sup>	Abex Corporation Oxnard, CA	F04606-69-A-0120S0
320	Transformer Assy	" "	" "
320	Cooling Coil <sup>2</sup>	Harrison Radiator Lockport, NY	F34601-69-C-2075
320	Valve <sup>2</sup>	" "	F34601-69-C-1953
160	Blower Assembly	Joy Mfg Company New Philadelphia, OH	F34601-69-C-2366

Note 1. This motor-pump assembly was manufactured by New York Airbrake for the first 125 kits. The cost savings to be accrued by switching vendors was offset by flight qualification, fit, spares and data problems.

Note 2. This part was one of two comprising the Group B component formerly known as the Oil Cooler.

Source: Worksheet, OCAMA(MMNO).

listing when combined with Bendix supplied components comprises the total complement of Group B items.

Each of these contracts is a microcosm. A thorough chronological history of the modification program would require a complete accounting of each contract. Personal resources prohibited such a detailed search. Only one contract, F34601-69-C-4073, will be discussed in detail since it has the largest dollar value.

Procurement action on Contract C-4073 began in November 1968 when the Purchase Request was initiated. Although a Request for Proposal (RFP) was issued in December, the contract was not issued until 21 July 1969. This delay was due to difficulties experienced by OCAMA in obtaining adequate cost information from the contractor. Contract C-4073 was awarded to Weston Hydraulics, Division of Borg-Warner Corporation, Van Nuys, California for 320 elevator actuators and 160 rudder actuators. It was a Firm Fixed Price (FFP) type contract at a price of \$3,186,321.60 which included a profit factor of 10.1%. Deliveries were to commence in March 1970 and be completed by March 1971. Four Change Orders were processed on this contract at the time of the research.

P001-14 May 70: Increased the quantity of elevator actuators by 12 and the rudder actuators by 6; deliveries were to be made between June and August 1970 with a contract price increase of \$119,577.

P002-13 Jun 70: Allowed a change in item configuration at an increase in price of \$94,845. This made the new contract price \$3,400,744.

P003 and P004 were shipping schedule and configuration changes, but apparently at no increase in price.<sup>42</sup>

#### Program Costs and Aircraft Schedules

While the detailed contractual actions described above were occurring, HQ AFLC and HQ USAF were concerned with the larger aspects of the total modification program, specifically costs and aircraft schedules.

In the area of program costs, in response to a HQ USAF request to update the MPD, OCAMA approved and submitted an AFLC Form 48 titled, B-52G/H Stability Augmentation and Improved Flight Control Systems, dated 24 March 1969. The cost breakout by Fiscal Year and Budget Program is shown in Table 4C. This form was revised and resubmitted by OCAMA in accordance with the guidance provided by HQ AFLC on 23 April 1969. The revised AFLC Form 48 of 28 April 1969 included the latest total of BP 1600 funds, deleted references to the prototype program costs and provided a clearer, more concise accounting of costs and differences in cost between the MPD and the current program. The Form 48 also stated the total program cost requirement to be \$68.7M.<sup>43</sup> The revised form was approved by the HQ AFLC CCB on 7 May 1969.

There had been no prior submission of an AFLC Form 48 on this modification. Based on the data and justification provided in the Form 48 of April 1969, an amendment to the original MPD was issued by HQ USAF. The amendment to Mod No 10007 of 11 July 1969 revised only the funding statement. The revised estimated cost for fleet incorporation was stated as \$68.7M, but the funding by Budget Program and Fiscal Year as shown in Table 5C totalled \$69.1M.<sup>44</sup> The figure for the BP 1100/FY 69 is \$0.4M greater in the MPD Amendment than in the AFLC Form 48. Reference Table 1C for the original MPD Cost Breakout.

BP 1100 cost increases were attributable to the prime contractor, Boeing, underestimating the cost of items to be supplied by vendors. However, part of this cost increase was offset by actions taken to reduce the kit cost, such as revisions to the electronics package and direct buys from the vendors. BP 1600 spares costs increased due to the increased cost of vendor components and changes in quantities approved by the provisioning committees. No information was provided regarding the 1P00 expense spares or changes in DMIF costs.<sup>45</sup>

Table 6C provides the cost breakout available in AFLC records at the time the research was conducted.

The B-52 aircraft input/output schedules were the result of a coordinated effort among SAC/OCANA/SAAMA.

Table 4C  
AFLC Form 48 Cost Breakout<sup>1</sup>

	FY 66	FY 67	FY 68	FY 69	FY 70	FY 71	Total
BP 1100	\$6.7	2.7	21.2	30.4	2.5		63.5
BP 1600			2.2	1.4			3.6
DMIF <sup>2</sup>				.1	3.9	3.9	7.73
Total	\$6.7	2.7	23.4	31.9	6.4	3.9	74.93

Note 1. Costs in millions of dollars.

Note 2. Accounting change, was P 431.

Note 3. Columns/rows may not total because of rounding errors.

Source: AFLC Form 48, 24 Mar 69.

Table 5C  
Current Modification Program Directive Cost Breakout<sup>1</sup>

	FY 68	FY 69	FY 70	FY 71	Total
BP 1100	\$21.2	30.8	2.5		54.5
BP 1600	3.0	2.8			5.8
IP00 <sup>2</sup>		.4			.4
DMIF		.1	3.8	4.5	8.4
Total	\$24.2	34.1	6.3	4.5	69.1

Note 1. Costs in millions of dollars.

Note 2. Expense spares.

Source: Amendment to MPD, 11 Jul 69.



Table 6C  
Modification Number 10007 Cost Breakout<sup>1</sup>

	FY 68	FY 69	FY 70	FY 71	FY 72	Total
BP 1100	\$21.2	33.5	2.5			54.2
BP 1600	3.0	3.3				6.3
6H <sup>2</sup>		.5	.7			1.1
6E <sup>3</sup>		.1	3.6	4.3	.1	8.1
Total	\$24.2	34.3	6.8	4.3	.1	69.7

Note 1. Costs in millions of dollars.  
 Note 2. Accounting code for expense spares.  
 Note 3. Accounting code for DMIF  
 Source: HQ AFLC RCS: D-17, as of 30 Jun 70.

The airplane receives the modification kit either during its scheduled maintenance cycle or during a special drop-in program. The B-52G/H has a three year IRAN cycle. Since the MPD required the modification be accomplished in two years, a special fly-in program was instituted. The aircraft schedules in part are based on kit availability and resolution of then pending technical problems, such as, EMI, electronics unreliability, or pump flight qualification. Table 7C displays the SAAMA/OCAMA actual input/output schedules for installation of Mod No 10007 on the B-52G/H aircraft.

As of 30 October 1970, 152 B52 aircraft had the SAS modification installed, and the program was to continue at the average output rate of 10.5 per month. The last input was forecast for July 1971; the program is scheduled to be complete when the last aircraft is output from OCAMA in October 1971. At the time of the research there appeared to be no major or significant cost/schedule/performance problems. This is not to say that problems of a fire-fighting nature were not occurring daily.

(Researcher's Note. Not included in the aircraft schedule data is one modification performed at Boeing on the prototype aircraft nor the modification of two test aircraft. One test aircraft is scheduled into SAAMA in March 1972 and out by June 1972, while the second is

**Table 7C**  
**B-52 Stability Augmentation System Installation Schedule - Actual**

CY 1969													CY 1970									
A	M	J	J	A	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O			
<u>Input</u>																						
SAAMA	1	0	0	3	4	5	3	5	4	9	6	9	8	7	7	8	7	6	6			
OCAMA	0	1	0	2	7	1	5	4	4	4	5	6	6	6	7	6	7	7	7			
Cum Tot	1	2	2	7	18	24	32	41	49	62	73	88	102	115	129	143	157	170	183			
<u>Output</u>																						
SAAMA	0	0	0	0	0	1	2	5	4	5	5	9	8	8	8	8	7	5	7			
OCAMA	0	0	0	0	1	0	3	3	5	4	4	5	5	6	7	6	7	7	7			
Cum Tot	0	0	0	0	1	2	7	15	24	33	42	56	69	83	98	112	126	138	152			
Source: OCAMA(MMAO).																						

( scheduled into OCAMA in December 1971 and out by March 1972.)

### Summary

This section recaps some of the pertinent aspects of the cost/schedule/performance characteristics of the B-52G/H Stability Augmentation System (SAS) Program with emphasis on the HQ USAF directed Class IV Mod No 10007. The summary is as of October 1970 when the data was collected. The second subsection of this summary is a commentary by the researcher.

### Cost/Schedule/Performance

( A modification program to improve the stability augmentation system of the B-52G/H airplane was approved by HQ USAF in October 1967. Approval for this modification, No 10007, stemmed from studies, data and a prototype program which spanned three years and cost approximately twelve million dollars. The prototype program demonstrated the feasibility of the concept and design and the performance of the hardware in a true 'fly-before-buy' concept, i.e., demonstrated performance before committing large dollar sums to production.

( Initial planning estimates for program costs and schedules were based on contractor furnished data; data which assumed award of the 288 modification kits as a

single, complete buy coupled with a joint depot/contractor kit installation effort. At this same time plans were being formulated within OCAMA for purchasing the modification kits in two increments because of potential cost savings. The program was approved at an estimated cost of \$60.1M with aircraft to commence input for kit installation by April 1969 and complete input by June 1971.

At present the program is estimated to cost \$69.7M. In some respects it is not the same program. Because of aircraft attrition, 283 aircraft will receive the modification. The production modification kit is not the same as the prototype kit because of the deletion and repackaging of black boxes in the yaw axis electronics and other attendant configuration changes. The quantities of provisioned items are now firm and different from those envisioned at program initiation.

The definition/requirement of Mean Time Between Failure (MTBF) used in this program is "The system MTBF, defined as the mean time between unscheduled maintenance actions caused by failure of ECP 1195K equipment, shall not be less than 100 system operating hours." OCAMA records indicated that this MTBF goal was achieved in June 1970 and the current MTBF is 110 hours, if the early gyro failures are excluded.<sup>46</sup>

Notwithstanding the difficulties encountered in contractual matters, funding, hardware design and quality

deficiencies, kit slippages, AGE and test equipment delinquencies, the numerous coordination interfaces required, and satisfying the desires of the using command (SAC), the program has produced a system which appears to meet its original technical objectives and aircraft schedules; objectives and schedules set 3-5 years earlier.

#### Commentary

The case history of the total B-52 Stability Augmentation System Program was pieced together from numerous records and interviews at HQ AFLC and OCAMA. Because of personal resource limitations, certain aspects of this modification program could not be thoroughly investigated and researched. This subsection relates some of the observations and reflections of the researcher; some that could not be explicitly substantiated or corroborated.

To document a large modification case history emphasizing costs, schedule and performance is a formidable task. The task was complicated by the functional organizational structure of the AFLC procurement process and by the length of time a large modification program spans. Each office at OCAMA had varying amounts of documentation on the program, especially as it related to their area of responsibility. The procurement

records, such as 'Narration of the Procurement Action' and the 'Pricing Memorandum,' are excellent summaries of a particular contract or portion of a program. No similar tracks could be found in the program management records. Record disposition policies which eliminate files in excess of two or three years contributed to earlier portions of the history being somewhat sketchy. Personnel turnover caused by retirement, reassignment or promotion further complicated assembling tracks of the program history.

To speak of 'a' program schedule is meaningless, for a variety of shipping schedules and program decision milestones exist. For example, in this program there were separate shipping schedules from Boeing for the first 125 basic ECP 1195K kits and for kit revisions R8, R17, R19 and R20; separate shipping schedules for each of the Group B components; schedules for delivery of installation tools, Mobile Training Units, and various data items; separate schedules for the numerous spares and AGE items and for the kits to modify the spares and AGE; and last, the schedule to modify the airplanes. There are also decision making schedules and program milestones. For example, Boeing's initial budget and schedule quotes were applicable only if the program was authorized by 1 November 1967; each letter contract had milestones for negotiation and definitization.

One must exert care when evaluating the statement that "The program has met or slipped its schedule."

Considerable effort had to be spent developing an accurate, consistent, chronological cost track record. Cost data was available in the LOG D-20 and D-17 reports, in the MPD, in the AFLC Forms 48 and in correspondence files. The categories by which these cost tracks are recorded vary. Besides differentiating among accounting and budget codes (codes which changed over the years the program was in existence), costs were also recorded by fiscal year and various categories, such as labor/engineering/hardware and required/approved/funded. The numbers and codes were not always consistent. The records do not always document why a change was made. Modification funds are frequently reprogrammed. Reprogramming requires explanations and justification. Many personnel are involved in this effort; personnel who are also subject to turnover.

It appeared that two pressures weighed heavily on this modification and its procurement and program management personnel. The first was the pressure to stay within approved cost levels, or put another way, to avoid any cost increases (and the resultant justification required) over this limiting figure. The decision to reorganize the yaw axis electronics is an example of this pressure. The second was the pressure to meet schedules



once established. The overriding schedule consideration in this program is the aircraft schedule; a schedule established in October 1967. Adherence to this schedule requirement to input all B-52G/H aircraft for modification between April 1969 and June 1971 dictated many program decisions.

Using 20/20 hindsight, it appears that the Boeing proposal of 15 September 1967 was optimistically biased for the complete modification of 288 aircraft. At the same time it is interesting to note how the 125 kit cost grew once Boeing became convinced of the OCAMA intention to use a two-buy concept. It would also be interesting to pursue this program history via a thorough review of contractor documentation, a serious deficiency of this study, but one which could not be accomplished within the framework available. The two-buy concept appeared to have been a foregone conclusion at OCAMA; the receipt of the Boeing proposal for \$51.2M provided the vehicle for going direct to the vendors. The purchase of the initial 125 kits from Boeing also bought a system integration capability, one perhaps not available at OCAMA. Once the component vendors were selected, the interface and integration problems overcome and the lines of communication established, OCAMA could then perform the system integration task in-house rather than contracting it to Boeing.

A total cost chart could not be derived for this program as was done for the C-130 Center Wing Program (Appendix B). The scope of this program did not permit detailed cost figures to be obtained for many portions of the program. Guesstimates would be subject to a large variance. Any chart so derived could be misleading and subject to misinterpretation. However, some of the costs which should be considered in preparing such a chart would be those associated with: all contracts with industry related to this program, including those related to the engineering test and evaluation of the modification; all studies; all labor, material and overhead charges for the installation effort; and aircraft downtime applicable to the modification. To be comparable to the C-130 chart, no costs would be included for Government in-house engineering and management effort or for the Using or Training Command resource expenditures. Any effort at a cost-benefit, cost-effectiveness or amortization plan should consider all of these costs.

Many people at HQ AFLC and OCAMA contributed to the compilation of this history. They were conscientious and hard-working. Their willingness to participate and aid in gathering the data and information necessary for this study was a vital ingredient in being able to document the above account.

Footnotes for Appendix C

1. B-52 Operational Life Studies, Directorate of Materiel Management, Tinker AFB, undated (circa December 1964).
2. Ibid.
3. Ibid.
4. Ibid.
5. ECP 1195K, as transmitted to OCAMA by Boeing letter #3-1150-39-84, 15 Sep 67.
6. ECP 1195 Program Review of September 1967, OCAMA (MMAO).
7. OCG Msg 20 2340 Dec 67.
8. B-52 System Support Program Report, LOG D-20, 31 Aug 67.
9. ECP 1195K, op. cit.
10. Ibid.
11. Ibid.
12. ECP 1195 Program Review, op. cit.
13. Modification Program Directive, "B-52 G&H ECP 1195," 4 Oct 67.
14. "Exhibit A, Narration of Procurement Action," Official Contract File, F34601-68-C-1902, OCAMA(OCPWA).
15. "ECP 1195 Stability Augmentation System," Official Contract File, F34601-68-C-1902, OCAMA(OCPWA).
16. Ibid.
17. RCS: AF-N-23, 28 Dec 67. OCAMA(OCPWD).
18. Exhibit A, op. cit.
19. B-52 System Support Program Report, LOG D-20, 31 Jan 68.

20. "ECP 1195 Stability Augmentation System," op. cit.
21. Ibid.
22. Ibid.
23. OCN Msg 8 1926 May 68.
24. OCPWC Memo, Price Increase ECP 1195, 17 May 68.
25. OCN Msg 17 1836 May 68.
26. Ibid.
27. OCN Msg 27 1611 May 68.
28. CSAF Msg 7 1911 Jun 68.
29. MCMT Msg 24 1909 Jun 68.
30. "Review of Maintainability/Cost Impact of Options," ECP 1195 Program, The Boeing Co., 22 May 68.
31. Official Contract File, F34601-68-C-1902, OCAMA (OCPWA).
32. Ibid.
33. "Electromagnetic Compatibility Investigation, Stability Augmentation System (SAS) and Liaison High Frequency (HF) Radio (AN/ARC-58)," Boeing Report D3-8134, 2 Oct 69.
34. OCPWA Memo, ECP 1195 SAS Kit Hardware Delivery Schedules, 3 Jul 69.
35. Discussion Item - ECP 1195, OCAMA/SAC Meeting, 23 Oct 69, OCN.
36. "Exhibit A to AFPI Fm 20," Official Contract File, F34601-69-C-2599, OCAMA(OCPWA).
37. AFLC Fm 48, B-52G/H Stability Augmentation and Improved Flight Control Systems, 28 Apr 69.
38. Official Contract File, F34601-69-C-2599, OCAMA (OCPWA).
39. ECP 1195 Program Review, OCAMA(MMROB).
40. Official Contract File, F34601-69-C-2685, OCAMA (OCPII).

41. Boeing Msg, Contract F34601-69-C-2685 (B-52 SASS),  
17 Dec 69.
42. Official Contract File, F34601-69-C-4073, OCAMA  
(OCPIA).
43. AFLC Fm 48, op. cit.
44. Amendment to MPD NO: B-52 G&H ECP 1195, 11 Jul 69.
45. AFLC Fm 48, op. cit.
46. Viewgraph, MTBF vs Flight Hours, ECP 1195 File,  
OCAMA(MMAO).

**APPENDIX D**

**AN EXCURSUS ON RESEARCHING DEFENSE PROCUREMENT**

## APPENDIX D

## AN EXCURSUS ON RESEARCHING DEFENSE PROCUREMENT

This Appendix is written as a guide for those contemplating performing research in defense procurement: scientific research on ways to analyze and improve the procurement of supplies, services and facilities for the Armed Services. It is based upon lessons learned in the conduct of this research and upon personal experiences while in Government procurement and contract administration.

A very interesting observation can be made after a review of the open literature for research and data published on procurement matters. It is the lack thereof. Although billions of dollars are spent each year on defense research, development, test, evaluation and procurement, only an extremely small amount appears to be expended on research in procurement methodology.

The research which is conducted can be separated into two groupings: external and internal. The majority of 'external research' is performed under contract to DOD or one of the Military Departments by non-profit or advisory companies such as the RAND Corporation, Institute for Defense Analysis (IDA), Center for Naval Analysis (CNA) and the Logistics Management Institute

(LMI). Although most of their business is with DOD, the bulk is not related to procurement. Copies of material they publish, which is not sensitive or classified, is available through the Defense Documentation Center, the Clearinghouse for Federal and Scientific Information and occasionally directly through the company. However, very little of this research is ever published in the open literature or technical journals.<sup>1</sup> The remaining external research is independent research, i.e., not sponsored by DOD. It is somewhat limited because of factors to be described later. 'Internal research' is that research conducted by DOD or the Military Service itself, using its own internal resources. Reports generated by internal research, since designed for internal management use and improvement, are often critical of the present mode: its design and operation. Such reports are usually labeled 'For Official Use Only' and rarely are published or widely disseminated. Therefore, the best data and latest research are generally not readily available to new researchers.<sup>2</sup>

One major source of procurement information is the texts of addresses made by prominent Government and industry officials. However, many of these speeches or papers reflect opinions or provide observations and thoughts.<sup>3</sup> Congress is another major source of information. Annual hearings on the Military Procurement and



Research & Development authorization and appropriation bills are conducted by the U.S. House of Representatives and Senate Armed Services and Appropriations Committees. In addition, other congressional committees, such as the Joint Economic Committee and Government Operations Committee, have periodically probed into the defense procurement business.<sup>4</sup> And, with increasing frequency over the last few years, Congress has called on its 'watchdog agency,' the General Accounting Office (GAO) to perform special investigations on selected procurement topics.<sup>5,6</sup> Generally, copies of the Committee hearings and reports, in addition to the GAO reports, are available to the public. Yet another source of information on defense procurement is industry. Through such organizations as the Aerospace Industries Association (AIA), the Electronic Industries Association (EIA) and the National Security Industrial Association (NSIA), defense contractors publish their collective viewpoint on some aspect of defense procurement.

The lack of scientific research and related publications in the field of procurement can be traced to two reasons. First, most useful data or information originates with the DOD or respective Military Service; thus, the researcher must obtain the data or permission to gather it from DOD. This will be dealt with in more detail later. Second, there are only a small number of

personnel who have both the expertise in research techniques and a procurement background.

The procurement business is complex and dynamic. It spans a broad spectrum from the legalities of contract clauses to the masses of administrative details to the parameters of technical weapon system performance.<sup>7</sup> It is studded with acronyms which seem to be growing at an exponential rate. It is not unusual for a person attempting research in defense procurement for the first time, or even an experienced researcher working in an unrelated or unfamiliar procurement area, to spend 50% or more of his time learning the process details and its terminology.

Having overcome the hurdle of 'learning the procurement business,' in order to communicate intelligently, the researcher then faces the next challenge, access to data and personnel. Research at this point can be broken into two categories, that sponsored by DOD and that not. The first category can be subdivided into research performed or not performed under contract. Examples of the former would be a study conducted by RAND<sup>8</sup>, while the latter would be an independent study, such as this thesis. The second category, research not sponsored by DOD, can also be divided into two subcategories: that research DOD must cooperate with and support, and that it need not. Examples of the former would be a GAO

investigation;<sup>5</sup> of the latter a request by Time or Ramparts.

The degree of cooperation the researcher receives will be a function of his research category. However, there is another factor, correlated to the first, which will directly affect the success of the researcher in obtaining the necessary data for his study. This factor is the level of 'sponsorship' for the contract or work. Investigations and studies performed by Commissions, vis., the Blue Ribbon Defense Panel appointed by President Nixon and Secretary of Defense Laird, and the Commission on Government Procurement established by Public Law 91-127, or by the RAND Corporation under contract to Headquarters, United States Air Force, will receive greater cooperation and access to data than research sponsored by a third level subcommand. The higher the granting and sponsoring authority, the broader the charter and authority. For procurement research to achieve its desired objectives, it must have sponsorship of sufficient authority, and the authority must be exercised if roadblocks in data gathering occur.

However, the task of the researcher in procurement does not end here, it merely begins.<sup>9</sup> Access to data does not guarantee availability or accuracy. Strange as it may seem with the large sums of money expended by DOD on management information systems, generating data banks

And making computer printouts, often the data desired is not available. And, usually what is available will be neither uniform nor random.<sup>10,11</sup> The researcher is then faced with the choice of obtaining the data via survey, required input reports, detailed research into files and records, personal interviews or any combination thereof. When confronted with these situations, certain pitfalls must be recognized. If the data is to be gathered via written survey or report, the needs must be stated in an explicit, precise and thorough manner, or else the results will be diverse, general and meaningless.<sup>12</sup> Backing of the sponsoring activity may be required to assure suspense dates are met. Now three situations can occur to complicate the research if record reviews and personal interviews are used. First, most large procurement programs span a considerable length of time, usually three to ten years. In this time personnel turnover occurs in the project office or procurement shop. Second, cost/funding accounting and coding systems, as well as management reporting systems and procedures, change over time. Third, the record disposition policy is such, that in many cases files are retired or destroyed after one or two years. Such a policy helps assure working space for project personnel. Thus, the researcher finds that project and procurement personnel are either no longer available or were not associated with the program or contract

at an earlier point in time. In addition, the records and files are scattered or are not available if the research extends beyond two years and are often difficult to correlate.

Another factor to be discussed, which relates not only to the availability and access to data, but also bears on the number of publications in the open literature. This factor is classification of the information, data or publication. The general classifications which confront the researcher are the security classifications of Confidential, Secret and Top Secret. Other classifications are For Official Use Only and Private, the two being synonymous, with the former used by Government and the latter by industry. Any one of these classifications may prevent the data from being readily available or published.<sup>13</sup> Military directives require a series of internal reviews for safeguarding military security before information or data can be released for publication.<sup>14</sup>

The last factor or pitfall to be covered is perhaps the most difficult of all for the researcher to recognize and overcome. This factor can be titled 'self-preservation.' Government procurement and security have much in common. Security deals with classified information which affects the security of the nation and its people; procurement of defense materials

also affects national security, and it generates expenditures of the people's money. To mishandle or error with one's own money is a personal matter. To do so, unintentional as it may be, with public money, is to stir the wrath of higher echelons, other Government agencies, Congress and the public. Vitriolic criticism of personnel responsible for large and small projects has caused more than one personnel shift or departure. A security violation or an error with public funds can have a far reaching personal impact. Therefore, a certain apprehension exists in the mind of the person furnishing data or being interviewed. In the overwhelming number of cases this apprehension is not because of their having personally erred, but because of the possible misinterpretation or misuse of the data and the consequent repercussions. A five minute interview or the completion of a short survey form may result in days or weeks of explaining, justifying and/or supplying supplemental data to higher headquarters to answer certain statements in the research report. This extra effort does not contribute to the individual's job, but rather it detracts because of the time spent. As a result, the researcher first finds a built-in reluctance to provide interviews and data. As one individual aptly stated it, "Who needs it?" Or another who said, "You only have to be bitten once to learn." Many of the individuals who must supply

the data or be interviewed will be at lower levels in the organization. Generally, they will fail to see the benefits to be derived from the research or study. They only see that time and effort must be taken from their normal, daily duties to provide data; data which, if misused or misinterpreted, will result in additional work, evoke criticism or perhaps even jeopardize their job security. Supervisory and higher levels of management in an organization being interviewed or supplying data pose a similar problem. Their present positions are the result of their achievements and performance, past and present. Most are battle-wary; many are protective and conservative. Most have been 'bitten,' at least once. Few desire the notoriety associated with being part of the research, much less the loss of manhours which may be required to support or contribute to the research, either on their part or their organization.

Because of the difficulties described above, the researcher must spend considerable time and effort cultivating his data source. This includes assuring and authenticating his authority, needs and intentions. Many contributors will request an opportunity to review the study before it is finalized. Still, the researcher must look at whatever data he may obtain with a jaundiced eye. Two questions must always be kept in mind: (1) Is this all the data available? and (2) Is it accurate and

free from bias? Avoiding all these pitfalls lengthens considerably the time required to gather meaningful and accurate data and information on procurement matters.

The researcher in procurement, perhaps more so than in other fields, often faces a situation which I choose to call 'the gardener's dilemma.' The analogy is along these lines. He has been given permission to dig on another's land in hopes of cultivating data which may later blossom forth with new ideas, theories or advances. However, occasionally he may stumble on some bones in the course of his digging. These bones belong to the 'bodies of past mistakes' that were made, buried and hopefully forgotten. The gardener's dilemma simply stated is: "Does he overlook the bones and pretend he never saw them, so as to continue digging and cultivating; or does he uncover them, show them and thereby possibly lose his digging rights?"

Performing research in defense procurement offers a real and worthwhile challenge. It is fraught with problems, difficulties and pitfalls. No matter how many articles or statements the uninitiated may read, or how many times he is told, the difficulty of doing such research becomes obvious only after one attempts it.

For the individual who desires to do research in procurement I offer these guidelines.



1. Learn the procurement process and language in general; your area of interest in detail.
2. Obtain a sponsoring activity/individual; one whose interests, stature and authority are commensurate with the research.
3. Recognize and anticipate the pitfalls which lie ahead.
4. Have patience, perserverance and empathy.
5. Believe in the research; its need to be accomplished and your desire to perform it.

Footnotes for Appendix D

1. Marshak, T. A., The Role of Project Histories in the Study of R&D, P-2850, The RAND Corporation, Santa Monica, California, January 1964, p. 2.

"The compilation of a number of detailed historical case studies began at RAND some years ago but because of security considerations only a few studies have been issued to the general public."

2. Ibid, p. iii.

"As is well known, scholarly investigation of R&D economics and decision making has suffered from a dearth of empirical and comparative materials, particularly data relating to military development projects."

3. Roback, Herbert, "From McNamara to Laird: Passing Reflections on Defense Procurement Reforms," Address to The National Security Industrial Association, Symposium on Defense Subcontracting, Washington, February 10, 1970.

". . . these remarks are tentative and rather generalized. The subject is worth scholarly treatment. In my job I do not have much time to reflect, and so I took just brief moments out to put these observations on paper."

4. U.S. Congress, Joint Economic Committee, Subcommittee on Economy in Government, The Economics of Military Procurement, USGPO, Washington, May 1969.

5. U.S. Comptroller General, General Accounting Office, Status of the Acquisition of Selected Major Weapon Systems, Comptroller General of the United States, Washington, February 6, 1970.

6. . . ., Action Required to Improve Department of Defense Career Program for Procurement Personnel, Comptroller General of the United States, Washington, August 13, 1970.

7. To "introduce (one) to the negotiation and management of defense contracts" Dean F. Pace requires 834 pages in his book, Negotiation and Management of Defense Contracts, Wiley-Interscience, New York, 1970.

8. Perry, R. L., et al., System Acquisition Experience, RM-6072-PR, The RAND Corporation, Santa Monica, California, November 1969.
9. In Cost Functions and Budgets (Cost Considerations in Systems Analysis), P-3789, The RAND Corporation, Santa Monica, California, February 1968, G. H. Fisher discusses: A major difficulty - the data problem, why there is a data problem, and provides some suggestions for dealing with it. (pp. 21-40)
10. Perry, op. cit., p. vii.  

"Various data retrieval systems exist, but the underlying problems of defining, categorizing, and understanding program growth are accentuated by lacunae, ambiguities, and uncertainties in the data."
11. Marshall, A. W. and Meckling, W. H., Predictability of Cost, Time and Success of Development, P-1821, The RAND Corporation, Santa Monica, California, December 11, 1959. Note 9.  

"The data Burssell was able to get are particularly messy. Therefore, a good deal of judgment has had to go into the construction of these estimates of factor increases. But even after the most prudent treatment, the data from which the factors were generated leave much to be desired and a good deal of caution is needed in interpreting the results."
12. Perry, op. cit., p. 1.  

"The questionnaire, therefore, sacrificed richness of detail in the interest of obtaining unambiguous answers that could be validated if the users desired."
13. In response to a data request, an OASD(I&L) letter of 6 January 1971 stated,  

". . . recommend that you proceed through Air Force channels in obtaining a copy of a SAR. The reason for this is that all of these reports are classified and any release would have to be controlled accordingly."
14. U.S. Air Force, Release of Information to the Public, AFR 190-12, January 10, 1969.

Continuation Sheet

Item 13. Abstract

Class IV aircraft modification programs were compiled: C-130 Center Wing Replacement and B-52 Stability Augmentation System Installation. The research indicates that large modification programs are micro-cosms of systems acquisitions and incur cost growth for similar reasons. The research also indicates the total modification program cost is not fully recognized. A methodology for further investigation is proposed.